EXHIBIT G

AO 120 (Rev. 08/10)

TO:	Mail Stop 8 Director of the U.S. Patent and Trademark Office P.O. Box 1450 Alexandria, VA 22313-1450	REPORT ON THE FILING OR DETERMINATION OF AN ACTION REGARDING A PATENT OR TRADEMARK

In Compliance with 35 U.S.C. § 290 and/or 15 U.S.C. § 1116 you are hereby advised that a court action has been filed in the U.S. District Court Eastern District of New York on the following

☐ Trademarks or ☑ Patents. (☐ the patent action involves 35 U.S.C. § 292.):

DOCKET NO.	DATE FILED	U.S. DISTRICT COURT
19-cv-6617	11/23/2019	Eastern District of New York

PLAINTIFF	DEFENDANT
Rondevoo Technologies, LLC	Keen Eye, LLC

	PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
1	~~See Complaint~~		
2	7,088,854		
3	7,254,266		
4	8,687,879		
5			

In the above—entitled case, the following patent(s)/ trademark(s) have been included:

DATE INCLUDED	INCLUDED BY ☐ Amendment ☐ Answer ☐ Cross Bill ☐ Other Pleading	
PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
1		
2		
3		
4		
5		

In the above—entitled case, the following decision has been rendered or judgement issued:

DECISION/JUDGEMENT

CLERK	(BY) DEPUTY CLERK	DATE
Douglas C. Palmer	L. Hong	12/16/2019

Copy 1—Upon initiation of action, mail this copy to Director **Copy 3—Upon termination of action, mail this copy to Director**
Copy 2—Upon filing document adding patent(s), mail this copy to Director **Copy 4—Case file copy**

EXHIBIT G

A31 PTO/SB/66
OMB 0651-00XX
U.S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

PETITION TO ACCEPT UNINTENTIONALLY DELAYED PAYMENT OF MAINTENANCE FEE IN AN EXPIRED PATENT (37 CFR 1.378(b))

Patent Number	Issue Date	Application Number	Filing Date	Docket Number (if applicable)
7088854	08-Aug-2006	10134157	25-Apr-2002	

CAUTION: Maintenance fee (and surcharge, if any) payment must correctly identify: (1) the patent number and (2) the application number of the actual U.S. application leading to issuance of that patent to ensure the fee(s) is/are associated with the correct patent. 37 CFR 1.366(c) and (d).

Applicants claims the following fee status:

- (•) Small Entity
- ( ) Micro Entity
- ( ) Regular Undiscounted

Applicants selects the following :

( ) 3 1/2	(•) 7 1/2	( ) 11 1/2

PETITION FEE
The petition fee required by 37 CFR 1.17(m) (Fee Code 1558/2558) must be paid as a condition of accepting unintentionally delayed payment of the maintenance fee.

MAINTENANCE FEE (37 CFR 1.20(e)-(g))
The appropriate maintenance fee must be submitted with this petition.

STATEMENT
THE UNDERSIGNED CERTIFIES THAT THE DELAY IN PAYMENT OF THE MAINTENANCE FEE TO THIS PATENT WAS UNINTENTIONAL

PETITIONER(S) REQUEST THAT THE DELAYED PAYMENT OF THE MAINTENANCE FEE BE ACCEPTED AND THE PATENT REINSTATED

THIS PORTION MUST BE COMPLETED BY THE SIGNATORY OR SIGNATORIES

37 CFR 1.378(c) states: "Any petition under this section must be signed in compliance with 37 CFR 1.33(b) ."

I certify, in accordance with 37 CFR 1.4(d)(4) that I am

- (•) An attorney or agent registered to practice before the Patent and Trademark Office who has been given power of attorney in this application.
- ( ) An attorney or agent registered to practice before the Patent and Trademark Office
- ( ) A sole patentee
- ( ) A joint patentee; I certify that I am authorized to sign this submission on behalf of all the other patentees as evidenced by the power of attorney in the application
- ( ) A joint patentee; all of whom are signing this e-petition
- ( ) The assignee of record of the entire interest that qualifies as an authorized party under 37 CFR 1.33(b)

EXHIBIT G

Attorney			
A signature of the applicant or representative is required in accordance with 37 CFR 1.33 and 10.18. Please see 37 CFR 1.4(d) for the form of the signature			
Signature	/Obi Iloputaife/		
Name	Obi Iloputaife	Registration Number	45677

EXHIBIT G

Electronic Patent Application Fee Transmittal

Application Number:	10134157
Filing Date:	25-Apr-2002
Title of Invention:	METHOD AND APPARATUS FOR GENERATING SPECIAL-PURPOSE IMAGE ANALYSIS ALGORITHMS
First Named Inventor/Applicant Name:	Carl W. Cotman
Filer:	Obi Iloputaife
Attorney Docket Number:	1418-P004001

Filed as Small Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Maintenance Fee Due at 7.5 years	2552	1	1800	1800
Pet. Delay Pymt Maintain Patent in Force	2558	1	850	850
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				

EXHIBIT G

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
			Total in USD ($)	**2650**

EXHIBIT G

UNITED STATES PATENT AND TRADEMARK OFFICE

Commissioner for Patents
United States Patent and Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450
www.uspto.gov

In re Patent No. 7088854
Issue Date: August 8,2006
Application No. 10134157
Filed: April 25,2002
Attorney Docket No. 1418-P004001

:
:DECISION GRANTING PETITION
:UNDER 37 CFR 1.378(b)
:

This is a decision on the electronic petition, filed August 11,2015 ,under 37 CFR 1.378(b) to accept the unintentionally delayed payment of the 7.5 year maintenance fee for the above-identified patent.

The petition is **GRANTED**.

The maintenance fee is accepted, and the above-identified patent reinstated as of August 11,2015 . This decision also constitutes notice that the fee has been accepted. An electronic copy of the petition and this decision has been created as an entry in the Image File Wrapper. Nevertheless, petitioner should print and retain an independent copy.

Telephone inquiries related to this electronic decision should be directed to the Electronic Business Center at 1-866-217-9197.

EXHIBIT G

Electronic Acknowledgement Receipt

EFS ID:	23178546
Application Number:	10134157
Patent Number:	7088854
Confirmation Number:	6192
Petition Issued Date:	August 11,2015
Title of Invention:	METHOD AND APPARATUS FOR GENERATING SPECIAL-PURPOSE IMAGE ANALYSIS ALGORITHMS
First Named Inventor/Applicant Name:	Carl W. Cotman
Customer Number:	60984
Filer:	Obi Iloputaife
Filer Authorized By:	
Attorney Docket Number:	1418-P004001
Receipt Date:	11-AUG-2015
Filing Date:	25-APR-2002
Time Stamp:	16:03:21
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	$2650
RAM confirmation Number	2490
Deposit Account	
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:	

EXHIBIT G

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Petition automatically granted by EFS	petition-request.pdf	32432 df552dd72cf9f1c15e939db6181887f62b9c6fad	no	2
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	31904 bf6216f865a6c6f75bb003b9f8378d5df038bab6	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	64336		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

EXHIBIT G

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	PATENT NUMBER	GROUP ART UNIT	FILE WRAPPER LOCATION
10/134,157	7088854	2624	9200

OC000000040339045

Correspondence Address/Fee Address Change

The following fields have been set to Customer Number 60984 on 02/26/2010

- **Correspondence Address**
- **Maintenance Fee Address**
- **Power of Attorney Address**

The address of record for Customer Number 60984 is:

60984
DALINA PASADENA
117 E. Colorado Blvd.
Suite 460
Pasadena, CA 91105

EXHIBIT G

OIPE JUN 15 2006 PATENT & TRADEMARK OFFICE

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

36067 7590 03/15/2006

DALINA LAW GROUP, P.C.
7910 IVANHOE AVE. #325
LA JOLLA, CA 92037

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission
I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/134,157	04/25/2002	Carl W. Cotman	86200.911	6192

TITLE OF INVENTION: METHOD AND APPARATUS FOR GENERATING SPECIAL-PURPOSE IMAGE ANALYSIS ALGORITHMS

APPLN. TYPE	SMALL ENTITY	ISSUE FEE	PUBLICATION FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	YES	$700	$300	$1000	06/15/2006

EXAMINER	ART UNIT	CLASS-SUBCLASS
ALAVI, AMIR	2621	382-165000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).
☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. Use of a Customer Number is required.

2. For printing on the patent front page, list
(1) the names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.
1 Dalina Law Group P.C.
2
3

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)
PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.
(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent): ☐ Individual ☐ Corporation or other private group entity ☐ Government

4a. The following fee(s) are enclosed:
☑ Issue Fee
☑ Publication Fee (No small entity discount permitted)
☐ Advance Order - # of Copies _____

4b. Payment of Fee(s):
☐ A check in the amount of the fee(s) is enclosed.
☑ Payment by credit card. Form PTO-2038 is attached.
☐ The Director is hereby authorized by charge the required fee(s), or credit any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. Change in Entity Status (from status indicated above)
☐ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27. ☐ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

The Director of the USPTO is requested to apply the Issue Fee and Publication Fee (if any) or to re-apply any previously paid issue fee to the application identified above.
NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature Joseph J. Mayo Date 6/15/2006
Typed or printed name Joseph J. Mayo Registration No. 53,288

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.
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06/16/2006 RMEBRAH1 00000067 10134157
700.00 OP
300.00 OP
01 FC:2501
02 FC:1504

EXHIBIT G

DALINA P.C.
LAW GROUP

FAX TRANSMISSION

To: Office of Patent Publication, ISSUE FEE
Fax No.: (571) 273-2885

From: JOSEPH J. MAYO (REG. NO. 53,288)
Fax No.: (858) 777-5425
Phone No.: (858) 442-5877

Total Number of Pages Including Cover: 4
Date: Thursday, June 15, 2006

US Serial No.: 10/134,157
Ref. No.: UC-P0004

Comments:

I hereby certify that this correspondence is being facsimile transmitted to the United States Patent and Trademark Office at FAX number 571-273-2885 on Thursday, June 15, 2006.

Fax Coversheet (1 page) (this sheet) Issue Fee Transmittal (1 page) Fee Transmittal PTOL-85 (1 page) Credit Card Payment Form (1 page)	Signature: /Joseph J. Mayo/ Date: Thursday, June 15, 2006

CONFIDENTIALITY NOTICE: This facsimile and any accompanying documents are confidential and may be legally privileged pursuant to the attorney-client privilege or considered attorney work-product. If you are not the intended recipient, any disclosure, reproduction, copying, distribution, or other dissemination or use of this communication is strictly prohibited. If you have received this transmission in error please immediately destroy all copies and notify the sender.

7910 Ivanhoe Ave., Ste. 325
La Jolla, California 92037
P. (866)221-6964

Joseph J. Mayo
D. (858) 442-5877
F. (858) 777-5425
jmayo@dalinalaw.com

EXHIBIT G

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

App. No.	:	10/134,157
Applicant	:	COTMAN, Carl
Filed	:	4/25/2002
TC/A.U.	:	2624
Examiner	:	ALAVI, Amir
Docket	:	UC-P0004
Customer No.	:	36067
Conf. No.	:	6192

For: METHOD AND APPARATUS FOR GENERATING SPECIAL-PURPOSE IMAGE ANALYSIS ALGORITHMS

Commissioner for Patents, ISSUE FEE
571-273-2885

Dear Sir:

ISSUE FEE TRANSMITTAL

In response to the Notice of Allowance and Fee(s) Due of 03/15/2006, please find the attached Issue Fee Transmittal (PTOL-85) and apply the enclosed Credit Card Payment Form (PTO 2038) towards the $700 Issue Fee for small entity status and the $300 Publication Fee for the above referenced application. Please use deposit account 502689 for any other charges not accounted for herein and please reference our file number UC-P0004 if accessing the deposit account.

Respectfully submitted,

Joseph J. Mayo, Reg. No.: 53,288
of THE DALINA LAW GROUP, P.C.
P. (858) 729-1927
F. (858) 777-5425

Correspondence Info: Customer Number **36067**	***CERTIFICATE OF TRANSMISSION*** *I hereby certify that this correspondence is being facsimile transmitted to the United States Patent and Trademark Office on June 15, 2006 to (571) 273-2885*
	Signature *Date: June 15, 2006*
	Name: Joseph J. Mayo

EXHIBIT G

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

NOTICE OF ALLOWANCE AND FEE(S) DUE

36067 7590 03/15/2006

DALINA LAW GROUP, P.C.
7910 IVANHOE AVE. #325
LA JOLLA, CA 92037

EXAMINER	
ALAVI, AMIR	
ART UNIT	PAPER NUMBER
2621	

DATE MAILED: 03/15/2006

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/134,157	04/25/2002	Carl W. Cotman	86200.911	6192

TITLE OF INVENTION: METHOD AND APPARATUS FOR GENERATING SPECIAL-PURPOSE IMAGE ANALYSIS ALGORITHMS

APPLN. TYPE	SMALL ENTITY	ISSUE FEE	PUBLICATION FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	YES	$700	$300	$1000	06/15/2006

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE REFLECTS A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE APPLIED IN THIS APPLICATION. THE PTOL-85B (OR AN EQUIVALENT) MUST BE RETURNED WITHIN THIS PERIOD EVEN IF NO FEE IS DUE OR THE APPLICATION WILL BE REGARDED AS ABANDONED.

HOW TO REPLY TO THIS NOTICE:

I. Review the SMALL ENTITY status shown above.

If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:

A. If the status is the same, pay the TOTAL FEE(S) DUE shown above.

B. If the status above is to be removed, check box 5b on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and twice the amount of the ISSUE FEE shown above, or

If the SMALL ENTITY is shown as NO:

A. Pay TOTAL FEE(S) DUE shown above, or

B. If applicant claimed SMALL ENTITY status before, or is now claiming SMALL ENTITY status, check box 5a on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and 1/2 the ISSUE FEE shown above.

II. PART B - FEE(S) TRANSMITTAL should be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). Even if the fee(s) have already been paid, Part B - Fee(s) Transmittal should be completed and returned. If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PTOL-85 (Rev. 01/06) Approved for use through 04/30/2007.

EXHIBIT G

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

36067 7590 03/15/2006

DALINA LAW GROUP, P.C.
7910 IVANHOE AVE. #325
LA JOLLA, CA 92037

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission
I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/134,157	04/25/2002	Carl W. Cotman	86200.911	6192

TITLE OF INVENTION: METHOD AND APPARATUS FOR GENERATING SPECIAL-PURPOSE IMAGE ANALYSIS ALGORITHMS

APPLN. TYPE	SMALL ENTITY	ISSUE FEE	PUBLICATION FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	YES	$700	$300	$1000	06/15/2006

EXAMINER	ART UNIT	CLASS-SUBCLASS
ALAVI, AMIR	2621	382-165000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).
☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) the names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.
1 _____
2 _____
3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual ☐ Corporation or other private group entity ☐ Government

4a. The following fee(s) are enclosed:
☐ Issue Fee
☐ Publication Fee (No small entity discount permitted)
☐ Advance Order - # of Copies _____

4b. Payment of Fee(s):
☐ A check in the amount of the fee(s) is enclosed.
☐ Payment by credit card. Form PTO-2038 is attached.
☐ The Director is hereby authorized by charge the required fee(s), or credit any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)
☐ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27. ☐ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

The Director of the USPTO is requested to apply the Issue Fee and Publication Fee (if any) or to re-apply any previously paid issue fee to the application identified above. NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

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EXHIBIT G

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/134,157	04/25/2002	Carl W. Cotman	86200.911	6192

36067 7590 03/15/2006

DALINA LAW GROUP, P.C.
7910 IVANHOE AVE. #325
LA JOLLA, CA 92037

EXAMINER	
ALAVI, AMIR	
ART UNIT	PAPER NUMBER
2621	

DATE MAILED: 03/15/2006

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment to date is 393 day(s). If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the Patent Term Adjustment will be 393 day(s).

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

PTOL-85 (Rev. 01/06) Approved for use through 04/30/2007.

EXHIBIT G

Notice of Allowability	Application No. 10/134,157	Applicant(s) COTMAN ET AL.	
	Examiner Amir Alavi	Art Unit 2621	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to *The election restriction of 09 May 2005*.

2. ☒ The allowed claim(s) is/are *1-27*.

3. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
   a) ☐ All b) ☐ Some* c) ☐ None of the:
      1. ☐ Certified copies of the priority documents have been received.
      2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
      3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

4. ☐ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   (a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review (PTO-948) attached
      1) ☐ hereto or 2) ☐ to Paper No./Mail Date _____.
   (b) ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☒ Notice of References Cited (PTO-892)
2. ☐ Notice of Draftperson's Patent Drawing Review (PTO-948)
3. ☐ Information Disclosure Statements (PTO-1449 or PTO/SB/08), Paper No./Mail Date _____
4. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
5. ☐ Notice of Informal Patent Application (PTO-152)
6. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____ .
7. ☒ Examiner's Amendment/Comment
8. ☒ Examiner's Statement of Reasons for Allowance
9. ☐ Other _____.

EXHIBIT G

EXAMINER'S AMENDMENT

- Applicant's election of Group I in the reply filed on 09 May 2005 is acknowledged. Because applicant did not distinctly and specifically point out the supposed errors in the restriction requirement, the election has been treated as an election without traverse (MPEP § 818.03(a)).
- This application is in condition for allowance except for the presence of claims 28-36 to being non-elected without traverse. Accordingly, claims 28-36 have been cancelled.
- An examiner's amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.
- The application has been amended as follows:
- Claims 28-36 are cancelled.
- Claim 25, line 11, please change, "said user", to read, "a user".
- Authorization for this examiner's amendment was given in a telephone interview with Mr. Joseph J. Mayo (Registration number 53,288), on 06 March 2006.

REASONS FOR ALLOWANCE

- The following is an examiner's statement of reasons for allowance: The present invention is directed to a computer program product for generating special purpose image analysis algorithms. Each independent claim identifies the uniquely distinct feature, " for obtaining at least one image having a plurality of chromatic data points, generating an evolving algorithm that partitions said plurality of chromatic data points within at least one image into at least one entity identified in accordance with a user's judgment and storing a first instance of said evolving algorithm as a product algorithm wherein said product algorithm enables the automatic classification of instances of said at least one entity within at least one second image in accordance with said judgment of said user". The closest prior art, Mathias et al. (USPN 6,480,627 B1), disclose wherein an evolutionary algorithm evolves alternative architectures and parameters for an image classification system, wherein a learning system is employed, and during the training period of the learning system, the architecture of the learning system

is evolved so as to create a learning system that is well suited to the particular classification problem set, in this manner, other parameters of the image classification system are evolved by the evolutionary algorithm, including those that effect image characterization, learning, and classification; while Guo et al. (USPN 6,993,185 B2), disclose method of texture based color document segmentation, either singularly or in combination, fail to anticipate or render the above underlined limitation obvious.

- Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

EXHIBIT G

Contact Information

- Any inquiry concerning this communication or earlier communications from the examiner should be directed to Amir Alavi whose telephone number is 571-272-7386.
- The examiner can normally be reached on Mon-Thu.. 8:00 am thru 6:30pm.If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Mr. Matthew Bella can be reached on 571-272-7778.
- The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300. Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only.
- For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

AA
Technology Division 2624
08 March 2006

EXHIBIT G

Notice of References Cited	Application/Control No. 10/134,157	Applicant(s)/Patent Under Reexamination COTMAN ET AL.	
	Examiner Amir Alavi	Art Unit 2621	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-6,480,627 B1	11-2002	Mathias et al.	382/224
*	B	US-6,993,185 B2	01-2006	Guo et al.	382/176
*	C	US-6,628,823 B1	09-2003	Holm, Jack M.	382/162
*	D	US-6,718,054 B1	04-2004	Lorigo et al.	382/128
*	E	US-6,813,373 B1	11-2004	Suri et al.	382/128
*	F	US-2002/0186882 A1	12-2002	Cotman et al.	382/165
*	G	US-2001/0009590 A1	07-2001	Holm, Jack M.	382/162
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

EXHIBIT G

Index of Claims

Application No.	Applicant(s)
10/134,157	COTMAN ET AL.
Examiner	**Art Unit**
Amir Alavi	2621

√	Rejected	–	(Through numeral) Cancelled	N	Non-Elected	A	Appeal
=	Allowed	+	Restricted	I	Interference	O	Objected

Claim		Date									
Final	Original	2/23/05	3-07-06								
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Issue Classification	Application/Control No.	Applicant(s)/Patent under Reexamination	
	10/134,157	COTMAN ET AL.	
	Examiner	Art Unit	
	Amir Alavi	2621	

ISSUE CLASSIFICATION

ORIGINAL CLASS	ORIGINAL SUBCLASS	CROSS REFERENCE(S) CLASS	CROSS REFERENCE(S) SUBCLASS (ONE SUBCLASS PER BLOCK)
382	165	382	224

INTERNATIONAL CLASSIFICATION
G 06K 9/00
G 06K 9/62
/
/
/

(Assistant Examiner) (Date)

(Legal Instruments Examiner) (Date) 3-9-06

Amir Alavi 03/08/2006

(Primary Examiner) (Date)

Total Claims Allowed: 27

O.G. Print Claim(s)	O.G. Print Fig.
1	11

☒ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
1	(1)		~~31~~										
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Search Notes

Application/Control No.	Applicant(s)/Patent under Reexamination
10/134,157	COTMAN ET AL.
Examiner	**Art Unit**
Amir Alavi	2621

SEARCHED			
Class	Subclass	Date	Examiner
382	128,162, 164,165, 173,181, 197	3/7/2006	A.A.
382	224,228	3/7/2006	A.A.
382	305	3/7/2006	A.A.
358	515,523	3/7/2006	A.A.
358	530	3/7/2006	A.A.
345	589,593	3/7/2006	A.A.
345	653,654	3/7/2006	A.A.
345	664,665	3/7/2006	A.A.

INTERFERENCE SEARCHED			
Class	Subclass	Date	Examiner
382	**165**	3/8/2006	**A.A.**
382	224	3/8/2006	A.A.
PGPUB Text	Searched	3/8/2006	A.A.
Interference search history		3/8/2006	A.A.

SEARCH NOTES (INCLUDING SEARCH STRATEGY)		
	DATE	EXMR
East & IEEE	3/7/2006	A.A.
Inventor name search	3/7/2006	A.A.
Interference search history printout	3/8/2006	A.A.

EXHIBIT G

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

BIBDATASHEET

Bib Data Sheet

CONFIRMATION NO. 6192

SERIAL NUMBER	FILING DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
10/134,157	04/25/2002 RULE	382	2621	86200.911

APPLICANTS

Carl W. Cotman, Santa Ana, CA;

Charles F. Chubb, Irvine, CA;
Yoshiyuki Inagaki, Irvine, CA;Brian Cummings, Irvine, CA;

** CONTINUING DATA ********** A.A. O.K.
This appln claims benefit of 60/286,897 04/25/2001

** FOREIGN APPLICATIONS ********** A.A. None

IF REQUIRED, FOREIGN FILING LICENSE GRANTED ** SMALL ENTITY **
** 06/03/2002

Foreign Priority claimed	STATE OR	SHEETS	TOTAL	INDEPENDENT
35 USC 119 (a-d) conditions met	COUNTRY	DRAWING	CLAIMS	CLAIMS
Verified and Acknowledged	CA	15	36	8

☐ yes ☒ no
☐ yes ☒ no ☐ Met after Allowance
Examiner's Signature A.A. Initials

ADDRESS
36067
DALINA LAW GROUP, P.C.
7910 IVANHOE AVE. #325
LA JOLLA , CA
92037

TITLE
Method and apparatus for generating special-purpose image analysis algorithms

FILING FEE	FEES: Authority has been given in Paper	
RECEIVED 724	No. _____ to charge/credit DEPOSIT ACCOUNT No. _____ for following:	☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other

EXHIBIT G

EAST Search History

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	1	(evolv$4 adj algorithm)and(partition$2)and(chromatic adj data)and(product)and(classif$5)	US-PGPUB	AND	ON	2006/03/08 09:15

EXHIBIT G

	Type	L #	Hits	Search Text	DBs
1	BRS	L1	10866	382/128,162,164,165,173,181,197,224,228,305;358/515,523,530;345/589,593,653,654,664,665.ccls.	US-PGPUB; USPAT; EPO; JPO; DERWENT
2	BRS	L2	106358	(color$2 or colour$2 or chrom$6)same(segment$6 or divid$4 or pars$4 or partition$4)	US-PGPUB; USPAT; EPO; JPO; DERWENT
3	BRS	L3	17145	(evolv$4)same(algorithm$2 or method$2)	US-PGPUB; USPAT; EPO; JPO; DERWENT
4	BRS	L4	2784	1 and 2	US-PGPUB; USPAT; EPO; JPO; DERWENT
5	BRS	L5	31	3 and 4	US-PGPUB; USPAT; EPO; JPO; DERWENT

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	Type	L #	Hits	Search Text	DBs
6	BRS	L6	91983	(evolv$4)and(algorithm$2 or method$2)	US-PGPUB; USPAT; EPO; JPO; DERWENT
7	BRS	L7	92	4 and 6	US-PGPUB; USPAT; EPO; JPO; DERWENT
8	BRS	L8	444232	(color$2 or colour$2 or chrom$6)and(segment$6 or divid$4 or pars$4 or partition$4)	US-PGPUB; USPAT; EPO; JPO; DERWENT
9	BRS	L9	2784	1 and 2	US-PGPUB; USPAT; EPO; JPO; DERWENT
10	BRS	L10	92	6 and 9	US-PGPUB; USPAT; EPO; JPO; DERWENT

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UNITED STATES PATENT AND TRADEMARK OFFICE

Commissioner for Patents
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DALINA LAW GROUP, P.C.
7910 IVANHOE AVE. #325
LA JOLLA, CA 92037

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OFFICE OF PETITIONS

In re Application of

Cotman, et al.

Application No. 10/134,157

Filed: April 25, 2002

Attorney Docket No. 86200.911

DECISION ON PETITION

This is a decision on the petition under 37 CFR 1.181(a) to withdraw the holding of abandonment, filed January 25, 2006.

The petition under 37 CFR 1.181(a) to withdraw the holding of abandonment is **granted**.

This application was held abandoned on April 10, 20005, after it was believed that no response was received to the restriction/election requirement mailed March 9, 2005. The notice allowed a period for reply of one (1) month from its mailing date. Extensions of the time set for reply were available pursuant to 37 CFR 1.136(a). A Notice of Abandonment was mailed on December 29, 2005, indicating that a reply to the notice was not received.

A review of the record reveals that a communication titled, "Request for Extension of Time, Response to Restriction under 35 USC 121" intending to be responsive to the election/restriction requirement was received on May 9, 2005, as evidenced by a review of the application file record. Applicant obtained an extension of time within the first month making the response filed May 9, 2005, timely. Based on the aforementioned, it appears that the application was improperly held abandoned as a response was received prior to expiration of the period for reply. The holding of abandonment is withdrawn, accordingly.

Further inquires regarding this decision may be directed to the undersigned at (571) 272-3222.

The application file is being forwarded Technology Center 2600, GAU 2621, for further processing.

Kenya A. McLaughlin
Petitions Attorney
Office of Petitions

EXHIBIT G

DALINA P.C.
LAW GROUP

FAX TRANSMISSION

CONFIDENTIAL COMMUNICATION

To: Commissioner for Patents
Fax No.: 571-273-8300

RECEIVED
CENTRAL FAX CENTER
JAN 25 2006

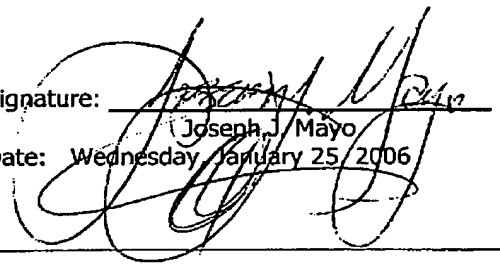
From: JOSEPH J. MAYO (REG. NO. 53,288)
Fax No.: (858) 777-5425
Phone No.: (858) 442-5877

Total Number of Pages Including Cover: **8**
Date: Wednesday, January 25, 2006

US Serial No.: **10/134,157**
Ref. No.: **UC-P0004**

Comments:

I hereby certify that this correspondence is being facsimile transmitted to the United States Patent and Trademark Office at FAX number 703-872-9306 on Wednesday, January 25, 2006.

Fax Coversheet (1 page) (this sheet) Petition to withdraw holding of abandonment (2 pages) PAIR printout and previous reply of 5/9/2005 (5 pages)	Signature:  Joseph J. Mayo Date: Wednesday, January 25, 2006

CONFIDENTIALITY NOTICE: This facsimile and any accompanying documents are confidential and may be legally privileged pursuant to the attorney-client privilege or considered attorney work-product. If you are not the intended recipient, any disclosure, reproduction, copying, distribution, or other dissemination or use of this communication is strictly prohibited. If you have received this transmission in error please immediately destroy all copies and notify the sender.

7910 Ivanhoe Ave., Ste. 325
La Jolla, California 92037
P. (866)221-6964

Joseph J. Mayo
O. (858) 442-5877
F. (858) 777-5425
jmayo@dalinalaw.com

EXHIBIT G

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

RECEIVED
CENTRAL FAX CENTER
JAN 25 2006

App. No.	:	10/134,157	Confirmation No.	6192
Applicant	:	COTMAN, et al.	Docket No. :	UC-P0004
Filed	:	04/25/2002	Customer No. :	36067
TC/A.U.	:	2621		
Examiner	:	ALAVI, Amir		

For: Method and Apparatus for Generating Special-Purpose Image Analysis Algorithms

Commissioner for Patents
571-273-8300

Dear Sir:

PETITION TO WITHDRAW HOLDING OF ABANDONMENT BASED ON EVIDENCE THAT A REPLY WAS TIMELY FILED UNDER 35 C.F.R. 181

Applicant hereby petitions the Primary Examiner to withdraw holding of abandonment for the above referenced application based on evidence that a reply was timely received. The Examiner made a requirement for restriction on 3/9/2005. Applicant replied in full on 5/9/2005. The Examiner abandoned the application on 12/29/2005 without observing the full response in PAIR. The primary examiner in the matter has requested a petition to withdraw holding of abandonment in order to reopen the file.

The primary examiner must decide the petition based on MPEP 1004, entitled Actions Which Require the Attention of a Primary Examiner, namely the event "Holding of abandonment for insufficient reply (MPEP § 711.03(a))." as listed in section 1004.

Please see the attached PAIR printout noting that the reply was received by the USPTO on 5/9/2005, which is 2 pages in length. Please find the actual reply attached as well, which is 3 pages in length. As the reply was received in full and is already in PAIR, the Primary Examiner is requested to withdraw holding of abandonment and duly examine the application as restricted. Please charge any fees associated with this petition to Deposit Account 502689 and reference with Attorney Docket No. UC-P0004. PLEASE CALL IF THERE ARE ANY QUESTIONS AT THE NUMBER INDICATED BELOW.

EXHIBIT G

Respectfully submitted,

Joseph J. Mayo, Reg. No.: 53,288
of THE DALINA LAW GROUP, P.C.
P. (866) 221-6964
F. (858) 777-5425

Correspondence Info: Customer Number **36067**	***CERTIFICATE OF MAILING*** *I hereby certify that this correspondence is being facsimile transmitted to the United States Patent and Trademark Office on January 25, 2006 to (571)273-8300 or is being deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.* Signature Name: Joseph J. Mayo *Date: January 25, 2006*

United States Patent and Trademark Office

PATENT APPLICATION INFORMATION RETRIEVAL

Full Reply as received in PAIR

Image File Wrapper for Application No.:10/134,157

NEW Changes to IFW Download - Updated:11/30/2004

This application is officially maintained in electronic form. To View: Click the desired Document Description. To Download and Print: Check the desired document(s) and click Download.

Mail Room Date	Document Description	Document Category	Page Count	All None Download
12/29/2005	Bibliographic Data Sheet	PROSECUTION	1	☐
12/29/2005	Abandonment	PROSECUTION	2	☐
05/09/2005	Extension of Time	PROSECUTION	3	☑
03/09/2005	Requirement for Restriction/Election	PROSECUTION	5	☐
03/09/2005	Index of Claims	PROSECUTION	1	☐
03/09/2005	Bibliographic Data Sheet	PROSECUTION	1	☐
03/16/2004	Communication - Re: Power of Attorney (PTOL-308)	PROSECUTION	2	☐
03/09/2004	Power of Attorney (may include Associate POA)	PROSECUTION	5	☐
04/25/2002	Fee Worksheet (PTO-875)	PROSECUTION	1	☐
04/25/2002	Claims Worksheet (PTO-2022)	PROSECUTION	1	☐
04/25/2002	Transmittal letter	PROSECUTION	2	☐
04/25/2002	Specification	PROSECUTION	73	☐
04/25/2002	Claims	PROSECUTION	16	☐
04/25/2002	Abstract	PROSECUTION	1	☐

PAGE 4/8 * RCVD AT 1/25/2006 4:21:01 PM [Eastern Standard Time] * SVR:USPTO-EFXRF-6/26 * DNIS:2738300 * CSID:858 777 5425 * DURATION (mm-ss):03-02

Jan 25 06 01:22p Dalina Law Group P.C. 858-777-5425 p.4

Case 1:20-cv-00589-MN Document 1-7 Filed 06/29/20 Page 33 of 172 PageID #: 164

EXHIBIT G

04/25/2002	Drawings	PROSECUTION	15	
04/25/2002	Oath or Declaration filed	PROSECUTION	3	
04/25/2002	Authorization for Extension of Time for all replies	PROSECUTION	2	
04/25/2002	Fee Worksheet (PTO-875)	PROSECUTION	1	

Sorted By : Mail Room Date

PAGE 5/8 * RCVD AT 1/25/2006 4:21:01 PM [Eastern Standard Time] * SVR:USPTO-EFXRF-6/26 * DNIS:2738300 * CSID:858 777 5425 * DURATION (mm-ss):03-02

Jan 25 06 01:22p Dalina Law Group P.C. 858-777-5425 p.5

Case 1:20-cv-00589-MN Document 1-7 Filed 06/29/20 Page 34 of 172 PageID #: 165

EXHIBIT G

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DALINA P.C. LAW GROUP

FAX TRANSMISSION

CONFIDENTIAL COMMUNICATION

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To: Commissioner for Patents
Fax No.: (703) 872-9306

From: JOSEPH J. MAYO (REG. NO. 53,288)
Fax No.: (858) 777-5425
Phone No.: (858) 442-5877

Total Number of Pages Including Cover: **4**
Date: Monday, May 09, 2005

US Serial No.: **10/134,157**
Ref. No.: **UC-P0004**

Comments:

I hereby certify that this correspondence is being facsimile transmitted to the United States Patent and Trademark Office at FAX number 703-872-9306 on May 9th, 2005.

Fax Coversheet (1 page) (this sheet)	
Response to Office Action (2 pages)	Signature: Joseph J. Mayo
Credit Card Payment Form (1 page)	Date: 5/9/2005

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7910 Ivanhoe Ave., Ste. 325
La Jolla, California 92037
P. (866)221-6954

Joseph J. Mayo
D. (858) 442-5877
F. (858) 777-5425
jmayo@dalinalaw.com

EXHIBIT G

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

App. No.	:	10/134,157	Confirmation No.	6192
Applicant	:	COTMAN, et al.	Docket No. :	UC-P0004
Filed	:	04/25/2002	Customer No. :	36067
TC/A.U.	:	2621		
Examiner	:	ALAVI, Amir		

For: Method and Apparatus for Generating Special-Purpose Image Analysis Algorithms

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Commissioner for Patents
703-872-9306
Sir:

REQUEST FOR EXTENSION OF TIME,
RESPONSE TO RESTRICTION UNDER 35 U.S.C. 121

This response addresses the restriction requirement of March 9th, 2005. Applicant hereby petitions the Commissioner of Patents to extend the time to reply to the office action by one month as per 37 CFR 1.136(a). A credit card payment form is included herewith to cover the cost of the extension. Applicant hereby elects Group I as designated by the Examiner, (corresponding to claims 1-27). Should the Examiner have any questions about this election and listing of claims readable thereon, please contact Applicant's representative at the number provided below. As applicant has addressed all issues raised by the Examiner, Applicant hereby requests examination on the merits. Please use deposit account 502689 for any other charges not accounted for herein and please reference our file number A2I-P0003 when using the deposit account.

Respectfully submitted,

Joseph J. Mayo, Reg. No.: 53,288
P. (866) 221-6864
F. (858) 777-5425

05/10/2005 HLE333 00000013 10134157
01 FC:2251 60.00 OP

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Correspondence Info: Customer Number 36067	*CERTIFICATE OF TRANSMISSION* *I hereby certify that this correspondence is being facsimile transmitted to the United States Patent and Trademark Office on May 9, 2005 to (703) 872-9306.*
	Signature *Joseph I. Mayo* *Date: May 9, 2005* Name: Joseph I. Mayo

EXHIBIT G

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/134,157	04/25/2002	Carl W. Cotman	86200.911	6192

36067 7590 12/29/2005

DALINA LAW GROUP, P.C.
7910 IVANHOE AVE. #325
LA JOLLA, CA 92037

EXAMINER	
ALAVI, AMIR	

ART UNIT	PAPER NUMBER
2621	

DATE MAILED: 12/29/2005

Please find below and/or attached an Office communication concerning this application or proceeding.

EXHIBIT G

Notice of Abandonment	Application No. 10/134,157	Applicant(s) COTMAN ET AL.	
	Examiner Amir Alavi	Art Unit 2621	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

This application is abandoned in view of:

1. ☒ Applicant's failure to timely file a proper reply to the Office letter mailed on *09 March 2005*.
   (a) ☐ A reply was received on _____ (with a Certificate of Mailing or Transmission dated _____), which is after the expiration of the period for reply (including a total extension of time of _____ month(s)) which expired on _____.
   (b) ☐ A proposed reply was received on _____, but it does not constitute a proper reply under 37 CFR 1.113 (a) to the final rejection.
   (A proper reply under 37 CFR 1.113 to a final rejection consists only of: (1) a timely filed amendment which places the application in condition for allowance; (2) a timely filed Notice of Appeal (with appeal fee); or (3) a timely filed Request for Continued Examination (RCE) in compliance with 37 CFR 1.114).
   (c) ☐ A reply was received on _____ but it does not constitute a proper reply, or a bona fide attempt at a proper reply, to the non-final rejection. See 37 CFR 1.85(a) and 1.111. (See explanation in box 7 below).
   (d) ☒ No reply has been received.

2. ☐ Applicant's failure to timely pay the required issue fee and publication fee, if applicable, within the statutory period of three months from the mailing date of the Notice of Allowance (PTOL-85).
   (a) ☐ The issue fee and publication fee, if applicable, was received on _____ (with a Certificate of Mailing or Transmission dated _____), which is after the expiration of the statutory period for payment of the issue fee (and publication fee) set in the Notice of Allowance (PTOL-85).
   (b) ☐ The submitted fee of $_____ is insufficient. A balance of $_____ is due.
   The issue fee required by 37 CFR 1.18 is $_____. The publication fee, if required by 37 CFR 1.18(d), is $_____.
   (c) ☐ The issue fee and publication fee, if applicable, has not been received.

3. ☐ Applicant's failure to timely file corrected drawings as required by, and within the three-month period set in, the Notice of Allowability (PTO-37).
   (a) ☐ Proposed corrected drawings were received on _____ (with a Certificate of Mailing or Transmission dated _____), which is after the expiration of the period for reply.
   (b) ☐ No corrected drawings have been received.

4. ☐ The letter of express abandonment which is signed by the attorney or agent of record, the assignee of the entire interest, or all of the applicants.

5. ☐ The letter of express abandonment which is signed by an attorney or agent (acting in a representative capacity under 37 CFR 1.34(a)) upon the filing of a continuing application.

6. ☐ The decision by the Board of Patent Appeals and Interference rendered on _____ and because the period for seeking court review of the decision has expired and there are no allowed claims.

7. ☐ The reason(s) below:

ANDREW W. JOHNS
PRIMARY EXAMINER

Petitions to revive under 37 CFR 1.137(a) or (b), or requests to withdraw the holding of abandonment under 37 CFR 1.181, should be promptly filed to minimize any negative effects on patent term.

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United States Patent and Trademark Office
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Alexandria, Virginia 22313-1450
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BIBDATASHEET

Bib Data Sheet

CONFIRMATION NO. 6192

SERIAL NUMBER	FILING DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
10/134,157	04/25/2002 RULE	382	2621	86200.911

APPLICANTS

Carl W. Cotman, Santa Ana, CA;

Charles F. Chubb, Irvine, CA;
Yoshiyuki Inagaki, Irvine, CA;Brian Cummings, Irvine, CA;

** CONTINUING DATA ********** A.A. O.K.
This appln claims benefit of 60/286,897 04/25/2001

** FOREIGN APPLICATIONS ********** A.A. None

IF REQUIRED, FOREIGN FILING LICENSE GRANTED ** SMALL ENTITY **
** 06/03/2002

Foreign Priority claimed	STATE OR	SHEETS	TOTAL	INDEPENDENT
☐ yes ☒ no	COUNTRY	DRAWING	CLAIMS	CLAIMS
35 USC 119 (a-d) conditions met ☐ yes ☒ no ☐ Met after Allowance	CA	15	36	8
Verified and Acknowledged Examiner's Signature A.A. Initials				

ADDRESS
36067
DALINA LAW GROUP, P.C.
7910 IVANHOE AVE. #325
LA JOLLA , CA
92037

TITLE
Method and apparatus for generating special-purpose image analysis algorithms

FILING FEE	FEES: Authority has been given in Paper	
RECEIVED 724	No. _____ to charge/credit DEPOSIT ACCOUNT No. _____ for following:	☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other

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LAW GROUP

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To: Commissioner for Patents
Fax No.: (703) 872-9306

From: JOSEPH J. MAYO (REG. NO. 53,288)
Fax No.: (858) 777-5425
Phone No.: (858) 442-5877

Total Number of Pages Including Cover: **4**
Date: Monday, May 09, 2005

US Serial No.: **10/134,157**
Ref. No.: **UC-P0004**

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Response to Office Action (2 pages)	Signature: Joseph J. Mayo
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Joseph J. Mayo
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F. (858) 777-5425
jmayo@dalinalaw.com

EXHIBIT G

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App. No.	:	10/134,157	Confirmation No.	6192
Applicant	:	COTMAN, et al.	Docket No. :	UC-P0004
Filed	:	04/25/2002	Customer No. :	36067
TC/A.U.	:	2621		
Examiner	:	ALAVI, Amir		

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For: Method and Apparatus for Generating Special-Purpose Image Analysis Algorithms

Commissioner for Patents
703-872-9306
Sir:

REQUEST FOR EXTENSION OF TIME,
RESPONSE TO RESTRICTION UNDER 35 U.S.C. 121

This response addresses the restriction requirement of March 9th, 2005. Applicant hereby petitions the Commissioner of Patents to extend the time to reply to the office action by one month as per 37 CFR 1.136(a). A credit card payment form is included herewith to cover the cost of the extension. Applicant hereby elects Group I as designated by the Examiner, (corresponding to claims 1-27). Should the Examiner have any questions about this election and listing of claims readable thereon, please contact Applicant's representative at the number provided below. As applicant has addressed all issues raised by the Examiner, Applicant hereby requests examination on the merits. Please use deposit account 502689 for any other charges not accounted for herein and please reference our file number A2I-P0003 when using the deposit account.

Respectfully submitted,

Joseph J. Mayo, Reg. No.: 53,288
P. (866) 221-6964
F. (858) 777-5425

05/10/2005 HLE333 00000013 10134157
01 FC:2251 60.00 OP

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Correspondence Info: Customer Number 36067	***CERTIFICATE OF TRANSMISSION*** *I hereby certify that this correspondence is being facsimile transmitted to the United States Patent and Trademark Office on May 9, 2005 to (703) 872-9306.*
	Signature *Joseph I. Mayo* *Date: May 9, 2005* Name: Joseph I. Mayo

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/134,157	04/25/2002	Carl W. Cotman	86200.911	6192

36067 7590 03/09/2005

DALINA LAW GROUP, P.C.
7910 IVANHOE AVE. #325
LA JOLLA, CA 92037

EXAMINER	
ALAVI, AMIR	

ART UNIT	PAPER NUMBER
2621	

DATE MAILED: 03/09/2005

Please find below and/or attached an Office communication concerning this application or proceeding.

EXHIBIT G

Office Action Summary	Application No.	Applicant(s)	
	10/134,157	COTMAN ET AL.	
	Examiner	Art Unit	
	Amir Alavi	2621	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 1 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on 25 April 2002.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) 1-36 is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☐ Claim(s) _____ is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☒ Claim(s) 1-36 are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☐ The drawing(s) filed on _____ is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☐ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☐ Information Disclosure Statement(s) (PTO-1449 or PTO/SB/08) Paper No(s)/Mail Date _____.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____.
5) ☐ Notice of Informal Patent Application (PTO-152)
6) ☐ Other: _____.

EXHIBIT G

Election/Restrictions

- Restriction to one of the following inventions is required under 35 U.S.C. 121:

I. Claims 1-27, drawn to classification, classified in class 382, subclass 224.

II. Claim 28, drawn to pattern recognizers, classified in class 382, subclass 159.

III. Claims 29-35, drawn to neural network, classified in class 382, subclass 156.

IV. Claim 36, drawn to thresholding, classified in class 382, subclass 172.

- The inventions are distinct, each from the other because of the following reasons:
- Inventions **I**, **II**, **III** and **IV** are related as combination and subcombination. Inventions in this relationship are distinct if it can be shown that (1) the combination as claimed does not require the particulars of the subcombination as claimed for patentability, and (2) that the

subcombination has utility by itself or in other combinations (MPEP § 806.05(c)). In the instant case, the combination as claimed does not require the particulars of the subcombination as claimed because image classification does not require particulars of thresholding. The subcombination has separate utility such as learning systems of neural networks.

- Because these inventions are distinct for the reasons given above and have acquired a separate status in the art as shown by their different classification, restriction for examination purposes as indicated is proper.
- Because these inventions are distinct for the reasons given above and the search required for Groups **II**, **III** and **IV**, is not required for Group **I**, restriction for examination purposes as indicated is proper.
- Applicant is advised that the reply to this requirement to be complete must include an election of the invention to be examined even though the requirement be traversed (37 CFR 1.143).
- Applicant is reminded that upon the cancellation of claims to a non-elected invention, the inventorship must be amended in compliance with 37 CFR 1.48(b) if one or more of the currently named inventors is no longer an inventor of at least one claim remaining in the application. Any amendment of inventorship must be accompanied by a request under 37 CFR 1.48(b) and by the fee required under 37 CFR 1.17(i).

EXHIBIT G

- Any inquiry concerning this communication or earlier communications from the examiner should be directed to Amir Alavi whose telephone number is 703-306-5913. The examiner can normally be reached on Mon-Thu.. 8:00 am thru 6:30pm.
- If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Mr. Bhavesh Mehta can be reached on 703-308-5246. The fax phone number for the organization where this application or proceeding is assigned is 703-872-9306.
- Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

AA
Group Art Unit 2621
23 February 2005

EXHIBIT G

Index of Claims

Application No.	Applicant(s)
10/134,157	COTMAN ET AL.
Examiner	**Art Unit**
Amir Alavi	2621

√	Rejected	–	(Through numeral) Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

Claim		Date
Final	Original	2/23/05
	(1)	+
	2	+
	3	+
	4	+
	5	+
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	10	+
	11	+
	12	+
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Claim	
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BIBDATASHEET

Bib Data Sheet

CONFIRMATION NO. 6192

SERIAL NUMBER	FILING DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
10/134,157	04/25/2002 RULE	382	2621	86200.911

APPLICANTS

Carl W. Cotman, Santa Ana, CA;

Charles F. Chubb, Irvine, CA;
Yoshiyuki Inagaki, Irvine, CA;Brian Cummings, Irvine, CA;

A.A. o.k.
** CONTINUING DATA **********
This appln claims benefit of 60/286,897 04/25/2001

A.A. None
** FOREIGN APPLICATIONS **********

IF REQUIRED, FOREIGN FILING LICENSE GRANTED ** SMALL ENTITY **
** 06/03/2002

		STATE OR	SHEETS	TOTAL	INDEPENDENT
Foreign Priority claimed	☐ yes ☒ no	COUNTRY	DRAWING	CLAIMS	CLAIMS
35 USC 119 (a-d) conditions met	☐ yes ☒ no ☐ Met after Allowance	CA	15	36	8
Verified and Acknowledged	Examiner's Signature A.A. Initials				

ADDRESS
36067
DALINA LAW GROUP, P.C.
7910 IVANHOE AVE. #325
LA JOLLA , CA
92037

TITLE
Method and apparatus for generating special-purpose image analysis algorithms

FILING FEE RECEIVED 724	FEES: Authority has been given in Paper No. _____ to charge/credit DEPOSIT ACCOUNT No. _____ for following:	☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other

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APPLICATION NUMBER	FILING OR 371 (c) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
10/134,157	04/25/2002	Carl W. Cotman	86200.911

CONFIRMATION NO. 6192

OC000000012109931

36067
DALINA LAW GROUP, INC.
7910 IVANHOE AVE. #325
LA JOLLA, CA 92037

Date Mailed: 03/16/2004

NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 03/09/2004.

The Power of Attorney in this application is accepted. Correspondence in this application will be mailed to the above address as provided by 37 CFR 1.33.

DAVINA G BUTLER
2600 (703) 308-9455

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EXHIBIT G

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10/134,157	04/25/2002	Carl W. Cotman	86200.911

CONFIRMATION NO. 6192

OC000000012109920

022804
THE HECKER LAW GROUP
1925 CENTURY PARK EAST
SUITE 2300
LOS ANGELES, CA 90067

Date Mailed: 03/16/2004

NOTICE REGARDING CHANGE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 03/09/2004.

- The Power of Attorney to you in this application has been revoked by the assignee who has intervened as provided by 37 CFR 3.71. Future correspondence will be mailed to the new address of record(37 CFR 1.33).

DAVINA G BUTLER
2600 (703) 308-9455

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Fax	:	(858) 777-5425
Phone	:	(866) 221-6964

Total Number of Pages Including Cover: 5
Date: March 9, 2004
Time: 10:25 AM

Our Ref. No.: UC-P0004
US Application Serial No.: 10/134,157
Examiner Name: UNKNOWN
Art Unit: UNKNOWN

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5 Pages TOTAL: Fax Coversheet (1 page); Revocation of Power of Attorney and Appointment of New Power of Attorney from each inventor(4 pages)	Signature: Joseph J. Mayo 3/09/2004 Joseph J. Mayo

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PTO/SB/82 (06-03)
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REVOCATION OF POWER OF ATTORNEY and APPOINTMENT OF NEW POWER OF ATTORNEY

Application Number	10/134,157
Filing Date	January 22, 2002
First Named Inventor	Cotman, et al.
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	UC-P0004

I hereby revoke all previous powers of attorney given in the above-identified application:

☐ A Power of Attorney is submitted herewith.

OR

☒ I hereby appoint the practitioners at Customer Number: 36067

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☒ The address associated with Customer Number: 36067

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☐ Firm or Individual Name					
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Telephone		Fax			

I am the:

☒ Applicant/Inventor.

☐ Assignee of record of the entire interest. See 37 CFR 3.71.
Statement under 37 CFR 3.73(b) is enclosed. (Form PTO/SB/96)

SIGNATURE of Applicant or Assignee of Record

Name	Charles F. Chubb, Ph.D.		
Signature	C. F. Chubb		
Date	3/8/04	Telephone	949-824-1481

NOTE: Signatures of all the inventors or assignees of record of the entire interest or their representative(s) are required. Submit multiple forms if more than one signature is required, see below*.

☐ *Total of _____ forms are submitted.

This collection of information is required by 37 CFR 1.36. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.
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SIGNATURE of Applicant or Assignee of Record

Name	Carl W. Cotman, Ph.D.		
Signature	Carl W. Cotman		
Date	3/5/04	Telephone	949-824-587

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SIGNATURE of Applicant or Assignee of Record

Name	Brian Cummings, Ph.D.		
Signature			
Date	3/02/04	Telephone	949-824-3254

NOTE: Signatures of all the inventors or assignees of record of the entire interest or their representative(s) are required. Submit multiple forms if more than one signature is required, see below*.

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☐ Assignee of record of the entire interest. See 37 CFR 3.71.
Statement under 37 CFR 3.73(b) is enclosed. (Form PTO/SB/96)

SIGNATURE of Applicant or Assignee of Record

Name	Yoshiyuki Inagaki		
Signature	Y. Inagaki		
Date	3/5/2004	Telephone	949-824-1746

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JC828 U.S. PTO 04/25/02

PTO 10/134157 04/25/02

PTO/SB/05 (11-00)
Approved for use through 10/31/2002. OMB 0651-0032
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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	86200.911
First Inventor	CARL W. COTMAN
Title	Method and Apparatus for Generating Special-Purpose ...
Express Mail Label No.	EL938707773US

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

1. [✔] Fee Transmittal Form (e.g., PTO/SB/17) *(Submit an original and a duplicate for fee processing)*
2. [ ] Applicant claims small entity status. See 37 CFR 1.27.
3. [✔] Specification [*Total Pages* 90] *(preferred arrangement set forth below)*
   - Descriptive title of the invention
   - Cross Reference to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to sequence listing, a table, or a computer program listing appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings *(if filed)*
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
4. [✔] Drawing(s) *(35 U.S.C. 113)* [*Total Sheets* 15]
5. Oath or Declaration [*Total Pages* 3]
   a. [✔] Newly executed (original or copy)
   b. [ ] Copy from a prior application (37 CFR 1.63 (d)) *(for continuation/divisional with Box 18 completed)*
      i. [ ] DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
6. [ ] Application Data Sheet. See 37 CFR 1.76
7. [ ] CD-ROM or CD-R in duplicate, large table or Computer Program *(Appendix)*
8. Nucleotide and/or Amino Acid Sequence Submission *(if applicable, all necessary)*
   a. [ ] Computer Readable Form (CRF)
   b. Specification Sequence Listing on:
      i. [ ] CD-ROM or CD-R (2 copies); or
      ii. [ ] paper
   c. [ ] Statements verifying identity of above copies

ADDRESS TO:

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Box Patent Application
Washington, DC 20231

ACCOMPANYING APPLICATION PARTS

9. [ ] Assignment Papers (cover sheet & document(s))
10. [ ] 37 CFR 3.73(b) Statement *(when there is an assignee)* [✔] Power of Attorney
11. [ ] English Translation Document *(if applicable)*
12. [ ] Information Disclosure Statement (IDS)/PTO-1449 [ ] Copies of IDS Citations
13. [ ] Preliminary Amendment
14. [✔] Return Receipt Postcard (MPEP 503) *(Should be specifically itemized)*
15. [ ] Certified Copy of Priority Document(s) *(if foreign priority is claimed)*
16. [ ] Request and Certification under 35 U.S.C. 122 (b)(2)(B)(i). Applicant must attach form PTO/SB/35 or its equivalent.
17. [ ] Other: .....

18. If a CONTINUING APPLICATION, *check appropriate box, and supply the requisite information below and in a preliminary amendment, or in an Application Data Sheet under 37 CFR 1.76:*

[ ] Continuation [ ] Divisional [ ] Continuation-in-part (CIP) of prior application No.: _____/_____

Prior application information: *Examiner* _____ *Group Art Unit:* _____

For CONTINUATION OR DIVISIONAL APPS only: The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 5b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

19. CORRESPONDENCE ADDRESS

[✔] *Customer Number or Bar Code Label* 022804 (Insert Customer No. or Attach Bar Code Label here) or [ ] *Correspondence address below*

PATENT TRADEMARK OFFICE

Name	The Hecker Law Group				
Address	1925 Century Park East Suite #2300				
City	Los Angeles	*State*	California	*Zip Code*	90067
Country	USA	*Telephone*	(310)286-0377	*Fax*	(310)286-0488

Name (Print/Type)	Cynthia A. Casby, Esq.	*Registration No. (Attorney/Agent)*	47,475
Signature		*Date*	April 25, 2002

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FEE TRANSMITTAL for FY 2002

Patent fees are subject to annual revision.

TOTAL AMOUNT OF PAYMENT ($) 724.00

Complete if Known	
Application Number	
Filing Date	
First Named Inventor	CARL W. COTMAN
Examiner Name	UNASSIGNED
Group Art Unit	UNASSIGNED
Attorney Docket No.	86200.911

METHOD OF PAYMENT

1. ☑ The Commissioner is hereby authorized to charge indicated fees and credit any overpayments to:

Deposit Account Number: 08-1520

Deposit Account Name: The Hecker Law Group

☑ Charge Any Additional Fee Required Under 37 CFR 1 16 and 1.17

☑ Applicant claims small entity status See 37 CFR 1 27

2. ☐ **Payment Enclosed:**

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FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
101	740	201	370	Utility filing fee	370
106	330	206	165	Design filing fee	
107	510	207	255	Plant filing fee	
108	740	208	370	Reissue filing fee	
114	160	214	80	Provisional filing fee	

SUBTOTAL (1) ($) 370.00

2. EXTRA CLAIM FEES

		Extra Claims		Fee from below		Fee Paid
Total Claims	36	-20** =	16	X 9	=	144
Independent Claims	8	- 3** =	5	X 42	=	210
Multiple Dependent					=	

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
103	18	203	9	Claims in excess of 20
102	84	202	42	Independent claims in excess of 3
104	280	204	140	Multiple dependent claim, if not paid
109	84	209	42	** Reissue independent claims over original patent
110	18	210	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) 354.00

**or number previously paid, if greater; For Reissues, see above

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
105	130	205	65	Surcharge - late filing fee or oath	
127	50	227	25	Surcharge - late provisional filing fee or cover sheet	
139	130	139	130	Non-English specification	
147	2,520	147	2,520	For filing a request for *ex parte* reexamination	
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action	
115	110	215	55	Extension for reply within first month	
116	400	216	200	Extension for reply within second month	
117	920	217	460	Extension for reply within third month	
118	1,440	218	720	Extension for reply within fourth month	
128	1,960	228	980	Extension for reply within fifth month	
119	320	219	160	Notice of Appeal	
120	320	220	160	Filing a brief in support of an appeal	
121	280	221	140	Request for oral hearing	
138	1,510	138	1,510	Petition to institute a public use proceeding	
140	110	240	55	Petition to revive - unavoidable	
141	1,280	241	640	Petition to revive - unintentional	
142	1,280	242	640	Utility issue fee (or reissue)	
143	460	243	230	Design issue fee	
144	620	244	310	Plant issue fee	
122	130	122	130	Petitions to the Commissioner	
123	50	123	50	Processing fee under 37 CFR 1.17(q)	
126	180	126	180	Submission of Information Disclosure Stmt	
581	40	581	40	Recording each patent assignment per property (times number of properties)	
146	740	246	370	Filing a submission after final rejection (37 CFR § 1.129(a))	
149	740	249	370	For each additional invention to be examined (37 CFR § 1 129(b))	
179	740	279	370	Request for Continued Examination (RCE)	
169	900	169	900	Request for expedited examination of a design application	

Other fee (specify) _____

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SUBMITTED BY				Complete *(if applicable)*	
Name (Print/Type)	Cynthia A. Casby, Esq.	*Registration No. (Attorney/Agent)*	47,475	*Telephone*	(310) 286-0377
Signature				*Date*	April 25, 2002

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04-30-02 EXHIBIT G

JC828 U.S. PTO 04/25/02

04/25/02 JC97 U.S. PTO 10/134157

PTO/SB/05 (11-00)
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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	86200.911
First Inventor	CARL W. COTMAN
Title	Method and Apparatus for Generating Special-Purpose ...
Express Mail Label No.	EL938707773US

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PATENT TRADEMARK OFFICE

Name	The Hecker Law Group				
Address	1925 Century Park East Suite #2300				
City	Los Angeles	*State*	California	*Zip Code*	90067
Country	USA	*Telephone*	(310)286-0377	*Fax*	(310)286-0488

Name (Print/Type)	Cynthia A. Casby, Esq.	*Registration No. (Attorney/Agent)*	47,475
Signature		*Date*	April 25, 2002

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Attorney Docket No.	86200.911

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Total Claims	36	-20** =	16	X 9	=	144
Independent Claims	8	- 3** =	5	X 42	=	210
Multiple Dependent					=	

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
103	18	203	9	Claims in excess of 20
102	84	202	42	Independent claims in excess of 3
104	280	204	140	Multiple dependent claim, if not paid
109	84	209	42	** Reissue independent claims over original patent
110	18	210	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) 354.00

**or number previously paid, if greater; For Reissues, see above

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
105	130	205	65	Surcharge - late filing fee or oath	
127	50	227	25	Surcharge - late provisional filing fee or cover sheet	
139	130	139	130	Non-English specification	
147	2,520	147	2,520	For filing a request for *ex parte* reexamination	
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action	
115	110	215	55	Extension for reply within first month	
116	400	216	200	Extension for reply within second month	
117	920	217	460	Extension for reply within third month	
118	1,440	218	720	Extension for reply within fourth month	
128	1,960	228	980	Extension for reply within fifth month	
119	320	219	160	Notice of Appeal	
120	320	220	160	Filing a brief in support of an appeal	
121	280	221	140	Request for oral hearing	
138	1,510	138	1,510	Petition to institute a public use proceeding	
140	110	240	55	Petition to revive - unavoidable	
141	1,280	241	640	Petition to revive - unintentional	
142	1,280	242	640	Utility issue fee (or reissue)	
143	460	243	230	Design issue fee	
144	620	244	310	Plant issue fee	
122	130	122	130	Petitions to the Commissioner	
123	50	123	50	Processing fee under 37 CFR 1.17(q)	
126	180	126	180	Submission of Information Disclosure Stmt	
581	40	581	40	Recording each patent assignment per property (times number of properties)	
146	740	246	370	Filing a submission after final rejection (37 CFR § 1.129(a))	
149	740	249	370	For each additional invention to be examined (37 CFR § 1 129(b))	
179	740	279	370	Request for Continued Examination (RCE)	
169	900	169	900	Request for expedited examination of a design application	

Other fee (specify) _____

*Reduced by Basic Filing Fee Paid **SUBTOTAL (3)** ($)

SUBMITTED BY				Complete *(if applicable)*	
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Signature				*Date*	April 25, 2002

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EXHIBIT G

UNITED STATES
PATENT APPLICATION

FOR

METHOD AND APPARATUS FOR GENERATING SPECIAL-PURPOSE IMAGE ANALYSIS ALGORITHMS

Express Mail #EL938707773US

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This application claims the benefit of United States Provisional Patent Application serial Number 60/286,897, filed on April 25, 2001 and entitled "METHOD AND APPARATUS FOR PERFORMING THE EXPERT QUANTIFICATION OF IMAGE DATA."

FIELD OF THE INVENTION

This invention relates to the field of computer software or hardware. More specifically, the invention relates to a method and apparatus for generating special-purpose image analysis algorithms based on the expert classification of image data.

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BACKGROUND

The ability to differentiate between a series of one or more objects comes naturally to human beings. A 5-year old with a set of building blocks can separate the blocks according to size, color, texture, and many other discernible characteristics. Most children can even add more categories to the classification scheme as new qualities appear. For example, as the building blocks age, the surface of the building blocks may

fade. If new blocks are introduced to the child, the child can easily tell the difference between the new blocks and the old blocks. Current computer systems, however, find such tasks enormously difficult. Existing systems for classifying objects contained within an image are inherently limited and cannot, for example, effectively identify how many objects of a particular type exist in an image. The limitations of existing technologies become increasingly evident when complex images are to be processed. For example, when the characteristics that distinguish one entity from another are subtle and vary from entity to entity, existing computer systems become unable to accurately classify entities in an image as belonging to a certain type.

There are many uses for an improved system that can reliably quantify entities across multiple sets of image data. For instance, scientists, laboratory technicians, doctors, and other professionals have a need for a technology that enables the extraction of quantitative information from an image. Accurately counting the number of entities in an image requires that the person performing the count understand the various forms and nuances associated with the types of entity being counted. A pathologist may be able to look at a particular red blood cell sample and approximate how many red blood cells are in that sample. A research biologist may need to quantify the number of entities present in a histological brain section for purposes of an experiment, but be prevented from doing so by the lack of time or expertise required to manually perform such an analysis. Similarly, a materials scientist may want to count the number of carbon fibers within a

cross section of a structural support but be prevented from doing so due to the large number of carbon fibers in the structural support.

Current systems do not have a mechanism for incorporating the expertise of people skilled at identifying a certain entity type. As a result, there is a need for an image classification system that can incorporate such expertise and give others the opportunity to benefit from it. For instance, while a histologist may have the patience to count a few given entities, he or she will usually do so only to a limited degree due to time and cost. Thus the scientific field has been dominated by illustrating findings with a few select captured images resulting in overly qualitative conclusions. When image classification is utilized to support a particular finding, it is typically done so in areas where the fields are not particularly crowded or where the entities of interest in an image are rarely represented. Counting the number of entities in a crowded image has been impractical. Similarly the counting of entities requiring searching over many fields is impractical. There is another key issue however in terms of consistency of entity assignment among viewers, whether they be inexperienced or professional. Entities often have different features and diverse forms despite the fact they belong to the same entity class. In many cases even the professional has their own distinct classification criteria that are not clearly defined, giving rise to inconsistent results across studies. The labor, monotony, and expertise required for the task often precludes investigation into avenues that may have significant merit, but that are exceedingly difficult to perform.

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Due to the problems associated with quantifying image data, there is a need for an improved technology that aids the process of obtaining quantitative data from images such as scientific samples. Such a technology has the potential to provide scientists and other users with important insights into the progression of many different diseases as well as the identification of distinguishing features among diseases. Likewise, chemists or materials scientists may discover new processes or improve compounds when aided in the classification and quantification of their unique images.

Some examples of current image quantification techniques and the problems associated with these techniques will now be discussed so as to provide the reader with an understanding of the need for an improved solution. Image Pro Plus, a software package for processing biological images, nicely exemplifies the standard approach to classification. Image Pro Plus™, is an example of a current system that provides a mechanism for counting, measuring, and/or classifying entities in digital images. Image Pro Plus provides the user with several methods for classifying pixels in terms of their colors. Image Pro Plus provides a mechanism for classifying entities in an image based on their morphology, but the system is difficult to use and does not "learn" how to improve its analytical skill over time. To classify the pixels in an image, the Image Pro Plus user must first interact with the application to define different pixel classes. For example, in the "color cube based dialog" Image Pro Plus divides the set of possible pixel colors into a cube, where a color corresponds to a point (r, g, b) in the cube with red, green and blue intensities r, g and b. The user defines as many distinct pixel classes as

he/she wishes. For each class, the user uses an eyedropper tool to select the colors he/she wants to include in the class. When all classes have been defined, Image Pro Plus displays an image in which pixels are partitioned into the appropriate pixel classes. If a given color has been included in two different classes, pixels of that color get assigned to whichever class was defined first.

What Image Pro Plus and other current systems lack is the ability to embody the knowledge of the trained histologist within a general tool that can be used to automate the classification of pixels and/or entities across a broad range of images. The importance of such a general tool lies in its potential to standardize the classification of histological structures across an entire biomedical field or subfield (e.g., the subfield focusing on Alzheimer's Disease). In addition, these same issues also hinder classification of image data in other scientific disciplines as well (e.g. materials science, chemistry, etc…).

Thus, there is a need for a system that improves upon the existing methodologies and systems for classifying image data. Such an improved system will now be described in detail.

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SUMMARY OF THE INVENTION

An embodiment of the present invention comprises a method and apparatus for generating special-purpose image analysis algorithms based on the expert classification of image data. One embodiment of the invention provides a process and related apparatus for obtaining quantitative data about a 2-dimensional, 3-dimensional image, or other dimensional image. For example, the invention is capable of classifying and counting the various different types of entities an image contains. Each entity comprises an object, structure, or some other type of identifiable portion of the image having definable characteristics (e.g., texture, shape, color, etc...). The entities located within an image may have a different shape, color, texture, or other definable characteristic, but still belong to the same classification. In other instances, entities comprising a similar color, and texture may be classified as one type while entities comprising a different color, and texture may be classified as another type. An image may contain multiple entities, and each entity may belong to a different class. Thus, the system embodying the invention may quantify image data according to a set of changing criteria and derive one or more classifications for the entities in the image. Once the image data is classified, the total number of each class of entity in the image may be calculated and presented to the user. Put simply, the invention provides a way for a computer to determine what kinds of entities are in an image and optionally count the total number of each class of entities that can be visually identified in the image. In one embodiment of the invention, the system is trained to perform such analysis by a user skilled at the identification of a particular

EXHIBIT G

object and/or entity. Once the system has been trained to master the classification process, the expertise gained during that training can be saved for subsequent usage by the same or a different user.

Some examples of the type of entity embodiments the invention may be configured to recognize include biological entities contained within histological sections, or physical entities in a material sample. Such biological entities may comprise any type of generalized cellular or non-cellular structure and the invention provides a mechanism for identifying and classifying different types of biological entities in a tissue section. For instance, the invention can evaluate stained tissue sections prepared by immunocytochemical and related techniques and determine what types of entities are contained in the tissue section and how many of those entities are present. Thus, a neuropathologist may utilize embodiments of the invention to classify and count the number of histological entities present in a digitized representation of a biological tissue section. However, the reader should note that the invention that will now be discussed herein is not limited to the realm of biological images alone. The system provides a mechanism for identifying any type of entity across any set of image data.

Obtaining quantitative data from histological sections in the study of dementias such as Alzheimer's Disease is crucial in understanding disease progression. However, due to the tedium of the manual counting task, systematic, large-scale counts are rarely obtained. If a tissue sample taken from a patient having Alzheimer's disease is evaluated, the system can identify tangles stained with reagents directed against tau as well as

plaques stained for Beta-Amyloid. Once these entities are identified, the system may count the number of tangles and plaques that are present in the image. Presently, the pathological diagnosis of Alzheimer's disease is based primarily on the presence or absence of plaques and tangles, but not on their absolute numbers because of the difficulties inherent in the quantification of these lesions and because of time constraints. A reproducible method of quantifying plaques and tangles across labs would allow more stringent classification standards. The problem of identifying cells in histological preparations has a long history in computer image processing. However, most researches have been focused on distinguishing cells from non-cells. Thus, there is a specific need in addition to the generalized need described above to have a program that can perform image processing in a way that can aid Alzheimer's research and/or any other scientific investigation that can utilize images.

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DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram that illustrates the classification of a plurality of different entities with an image.

Figure 2 illustrates a high-level view of the process used to evaluate image data to generate an algorithm based on feedback from a user that is capable of deriving quantitative information about entities within the image.

Figure 3 illustrates a high-level view of the additional process step utilized during evaluation of image data in accordance with one embodiment of the invention.

Figure 4 illustrates a high-level view of the additional process step utilized during evaluation of image data in accordance with one embodiment of the invention.

Figure 5 illustrates a high-level view of the methodology for processing image data using a neural network engine in accordance with one embodiment of the invention.

Figure 6 illustrates the process of selecting and initiating a user mode in accordance with one embodiment of the invention.

Figure 7 comprises a block diagram illustrating the various user modes in accordance with an embodiment of the invention.

Figure 8 illustrates the processing steps performed when the system is in automated user mode in accordance with one embodiment of the invention.

Figure 9 illustrates the processes associated with the independent user mode in accordance with one embodiment of the invention.

Figure 10 illustrates a general hardware environment that may be utilized to implement an embodiment of the invention.

Figure 11 illustrates the components incorporated within the system in accordance with one embodiment of the invention.

Figure 12 illustrates an original image to be processed in accordance with one embodiment of the invention.

Figure 13 illustrates a reconstructed outline of the original image in accordance with one embodiment of the invention.

Figure 14 illustrates a reconstructed outline of the original image in accordance with one embodiment of the invention.

Figure 15 illustrates a reconstructed outline of the original image in accordance with one embodiment of the invention.

Figure 16 illustrates a threshold image of a single entity example in accordance with one embodiment of the invention.

Figure 17 illustrates the relative Fourier descriptors of the example single entity (e.g., plaques).

Figure 18 illustrates a threshold image a double entity (e.g., biological entity such as plaques) in accordance with one embodiment of the invention.

Figure 19 illustrates the relative Fourier descriptors of the example double entity in accordance with one embodiment of the invention.

Figure 20 illustrates a threshold image a triple entity (e.g., biological entity such as plaques) in accordance with one embodiment of the invention.

Figure 21 illustrates the relative Fourier descriptors of the example triple entity in accordance with one embodiment of the invention.

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DETAILED DESCRIPTION

A method and apparatus for generating special-purpose image analysis algorithms based on the expert quantification of image data is described. In the following description numerous specific details are set forth in order to provide a more thorough understanding of the present invention. It will be apparent, however, to one skilled in the art, that embodiments of the present invention may be practiced without these specific details. In other instances, well-known features have not been described in detail so as not to obscure the invention.

The invention may be implemented in a hardware device and/or software form and may, for example, comprise computer readable program code tangibly embodied in a computer readable medium such as a processor, or memory coupled to the processor. In other instances, the invention executes in memory such as a hard disk, floppy disk, and/or or any other form of memory capable of storing computer readable program code. An embodiment of the invention contemplates the use of multiple computers to process image data and the invention may store or capture data image data in multiple locations accessible via a network.

System Overview:

One embodiment of the invention provides a process and related apparatus for obtaining quantitative data about a 2-dimensional, 3-dimensional image, or other

dimensional image. For example, the invention can be used to produce a product algorithm capable of classifying and counting the numbers of different types of entities an image contains in accordance with the judgment of the user. Each entity may comprise an object, structure, or some other type of identifiable portion of the image having definable characteristics (e.g., a texture, shape, size, color, density, etc…). The entities located within an image may have a different shape, color, texture, or other definable characteristic, but still belong to the same classification. In other instances, entities comprising a similar color, and texture may be classified as one type while entities comprising a different color, and texture may be classified as another type. An image may contain multiple entities, and each entity may belong to a different class. The system embodying the invention may be used to produce many different product algorithms, which may be used to classify image data according to different criteria,. Once the image data is classified using a particular product algorithm generated using an embodiment of the invention, the total number of entities in the image may be calculated and presented to the user. Put simply, the invention provides a way for a user to generate a product algorithm that can be used to determine what kinds of entities are in an image and count the total number of entities that can be visually identified in the image.

In one embodiment of the invention the system utilizes of a set of evolving algorithms (e.g., Bayes' Theorem, a neural network, or any other image classification algorithm) to evaluate image data. The system may utilize any one of the evolving algorithms to evaluate different features of the image and may execute multiple iterations

of each algorithm. For instance, the user interacts with the system to generate a product algorithm comprising two processing stages. A first stage of processing, for example, may classify image data based on color and/or texture, and a second stage of processing may then evaluate parts of the image based on shape. The use of the invention to evolve a product algorithm may require one or more iterations in which the system uses input from the user to refine its model of (i) the different classes of material composing entities in the image, and (ii) the different classes of entities occurring in the image. User input during the evaluation can modify the evolving product algorithm. For example, user input may be used by the system to change the parameters defining a certain class of entities thereby enabling the mechanism to evolve. Once an acceptable scheme has evolved (e.g., the probabilities and/or neural network analysis consistently classifies different entities correctly), the evolving algorithm may be locked in place to yield a first product algorithm. Then a daughter algorithm allowed to further evolve. Once an evolving algorithm is locked in place it may be referred to as a product algorithm that can be stored for subsequent usage by the same or a different user and applied to additional image sets for purposes of analysis.

Some examples of the type of entities product algorithms configured in accordance with embodiments of the invention may be trained to recognize include biological entities contained within histological sections. Such biological entities may include any type of generalized cellular or non-cellular structure, and the invention provides a mechanism for producing product algorithms capable of identifying and

classifying different types of biological entities in a tissue section according to various different criteria. For instance, the invention can be used to generate one or more product algorithms to evaluate stained tissue sections prepared by immunocytochemical and related techniques and determine what types of entities are contained in the tissue section and how many of those entities are present. Thus, a neuropathologist may utilize embodiments of the invention to generate product algorithms to classify and count the number of histological entities present in any digitized representation of a biological tissue section. For instance, if a tissue sample taken from a patient having Alzheimer's disease is evaluated, the system can be used to generate a product algorithm to identify tangles stained with reagents against tau as well as plaques stained for Beta-Amyloid. Once these entities are identified, the system may count the number of tangles and plaques that are present in the image.

It is important to note that the illustrations provided here are for exemplary purposes and the process utilized to quantify image data also has applications in arenas other than the identification of biological entities. The invention is not limited solely to the quantification of histological samples and is intended to have applications for analyzing other types of images. Thus, users may also utilize the process described herein to generate product algorithms to evaluate any type of digitized image and classify any of the entities in that image that have definable characteristics. These characteristics may change over time as the system and the user learns more about the structures being analyzed.

Example Image Classification:

Figure 1 is a block diagram that illustrates the classification of a plurality of different entities with an image. Referring now to Figure 1 for example, a representation of an image 100 comprising a group of entities 101-107 is shown. Embodiments of the invention provide a mechanism for producing a product algorithm to classify and identify the entities contained within the image. The mechanism embodying aspects of the invention may take the form of computer software, and the process or methodology captured for performing such classification can be utilized by multiple instances of such computer software. Each entity 101-107 represents a portion of a digitized image that has one or more definable characteristics. Entity 101 may represent a cellular or non-cellular entity, a tangible object, a person, thing, or a representation of a tangible object (e.g., a radar image of a particular airplane), person, or thing. Entity 101, has at least one characteristic and may, for example, be associated with the characteristics A, B, and C. Entity 102 may be associated with the characteristics D, E, and F. Entity 103 may be associated with the characteristics G, H, and I. Entity 104 may have a set of characteristics similar to entity 103. Entities 105 and 107 are associated with characteristics similar to those associated with entity 102. Entity 106 is associated with characteristics J, K, and L. In one embodiment of the invention, structures that have similar characteristics are placed into the same class. Thus, entities 103 and 104 may belong to class 1 and entities 102, 107, and 105, for example, may be assigned to class 2. Since entities 101 and 106 each have different characteristics, they are each assigned to

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their own class. Once the entities in an image are classified, the process utilized to make such a determination may be stored in the form of a product algorithm (e.g., an instance of the evolving algorithm) and the system may use that algorithm to count the number of entities in each class.

Overlapping entities (e.g., 103 and 104) are counted in accordance with one embodiment of the invention as separate structures. Class 1, for example, has a count 120 of two entities and class 2 has a count 121 of three entities. The remaining classes each have one entity. Thus, class 3 has a count 122 of one entity and class 4 has a count 123 of one entity. Once the entities are classified by an embodiment of the invention, a total count of the number of each type of entity can be performed. The process for making such entity classifications will now be discussed in more detail.

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High-Level Process Flow:

Figure 2 illustrates a high-level view of the process used to evaluate image data to generate an algorithm based on feedback from a user that is capable of deriving quantitative information about entities within the image. The process initiates when the system embodying the invention obtains an image having a number of chromatic data points (e.g., step 200). For instance, the system may capture a picture using a mechanism such as a digital camera, video camera, or scanning device. The invention contemplates the use of many different types of image acquisition devices and can be adapted to interface with any device capable of obtaining a digital image or representation of an

image. Most conventional video capture cards that provide a resolution of 640 x 480 or greater provide a sufficient basis for analysis. However, the system may be adapted to utilize image data of any resolution. True-color (24-bit) is used in one embodiment of the invention, since this provides a significant range of colors to evaluate. The invention is not limited, however, to the use of true-color and can process many different types of image data (e.g., black and white, grayscale, or color of arbitrary spectral dimension and of any bit depth).

Once the image acquisition device captures the image data, the captured image data is provided to the system where it is stored in memory or otherwise held for subsequent processing. Any computer readable medium capable of storing digital or analog data may be adapted to hold the captured image data. In one embodiment of the invention each chromatic data point represents a pixel or some other subset of the image data having an associated color value (e.g., RGB, CMYK, PMS, Pantone™, or any other definable color space). Each pixel may be a single dot or a series of interconnected dots (e.g., NTSC, PAL, etc..). The image may have millions of different chromatic data points. However, one or more of the chromatic data points may have an identical or similar range of values. For instance, the image may have two pixels that contain the same or similar RGB values. Each image contains one or more entities comprised of a plurality of chromatic data points. The entities are visual representations of structures, objects, or other portions of the image having definable characteristic that may be identified via the process of image quantification described herein.

Once the image is acquired the system begins to evaluate the image data to determine what portions of the image can be classified as certain entities. The initial evaluation may or may not involve user input (e.g., step 201). However, if user input is provided the system utilizes such input to aid the process of entity identification. In one embodiment of the invention, the system provides an initial guess as to which of the plurality of chromatic data points comprise an entity (e.g., step 202). There are multiple mechanisms by which the identification process of step 202 may occur. For example, the system may analyze the image to determine the number of pixels that fall within a color range (e.g., tolerance level). The tolerance or threshold that is utilized can be determined by the user or by the system. Embodiments of the invention allow the user to select an area of the image that contains an entity to be counted or classified. The selected area can be referred to as a sample set of chromatic data points. The user may, for example, select a single chromatic data point or a set of chromatic data points that comprises the entity or set of entities targeted for classification. The system then analyzes the sample set of chromatic data points identified by the user and uses the results of the analysis as a basis for identifying which parts of the image may contain an entity.

In other instances the user may identify which portions of the image are background. The system then uses that identification to approximate which chromatic data points are background and which may be entities. The system may also be configured to guess which parts of the image are background and which parts of the

image are not by using data gathered during analysis of other images identified as containing similar entities.

If the system was previously utilized to evaluate similar images, the system may be configured to utilize the information gathered during the previous analysis and utilize that information for initially approximating which portions of the image contain entities. In accordance with one embodiment of the invention identifying which of said plurality of chromatic data points comprises an entity (e.g., step 202) may also entail obtaining a probability that some or all of the chromatic data points that make up the image belong to one or more pixel classes (see e.g., Figure 3 step 300). For instance, the system may determine which parts of the image falls within a certain range or distribution of color values collectively referred to as a pixel class. Each image contains multiple pixel classes and the pixel classes may contain overlapping values. A first pixel class defined as comprising the color values 0,0,0 through 155, 23, 34 may overlap with a second pixel class when the second pixel class contains values that fall within the range defined by the first pixel class. The user may define the composition of the pixel class by selecting one or more chromatic data points from the image. Alternatively, in one embodiment of the invention, pixel classes are defined by density functions that assign non-zero values to all chromaticities. Thus, each pixel class may include all possible chromaticities. However, a given pixel-measure vector may have higher probabilities in some pixel classes than in others.

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The probability may be based in whole or in part on the identification made by the user and/or a previous analysis of an image identified as a certain type (e.g., a tissue section likely to contain cancer cells stained in a certain manner). Such probabilities may be referred to as prior probabilities, but can also contain additional measures for evaluating the image. Once various portions of the image are associated with one or more pixel classes (e.g., based on the RGB value of the sampled chromatic data point), the chromatic data points may be assigned to a certain pixel class based on the probability the data point belongs to that class (e.g., step 302). This initial approximation may be performed with or without user input. However, in one embodiment of the invention a user provides the system with information that can be used to help derive prior probabilities. The user may, for example, provide information based on the user's own experience that aids the system in determining the probability a pixel will belong to a certain class. As mentioned above, user input is not required and the system may assume at the outset that all classes (including background) are equally probable. Then after a few images have been classified (and ratified by the user e.g., at step 204), the system is able to obtain an understanding about a cross-section of the image population that may be used to estimate prior probabilities more accurately. The understanding is incorporated into the analysis performed by the system using the evolving algorithm and can be saved for later usage as a product algorithm. The system's ability to classify entities improves over time as the number of classified images held in an entity zoo increases (see e.g., Figure 9; elements 920-936). The entity zoo is discussed in further detail below.

Embodiments of the invention may be configured to perform varying iterations of analysis (e.g., using the same or various other methodologies or algorithms for evaluating the image data). The various types of analysis may be performed at the entity identification phase of the process and each iteration of analysis is designed to further refine the evolving algorithm's ability to classify image data.

In one embodiment of the invention, the system initiates an iteration of analysis where it groups the chromatic data points into maximal spatially connected subsets whose points are in the same pixel class (see e.g., Figure 4 step 400). In one embodiment of the invention, such maximal spatially connected subsets of chromatic data points may also be referred to as blobs, and the grouping of chromatic data points into blobs is referred to as blob partitioning. In this embodiment of the invention, entities are required to be blobs of different types. However, the invention contemplates relaxing these restrictions in several ways. First, blobs may be allowed to comprise not only maximal spatially connected subsets of pixels from the same class, but maximal subsets of pixels from the same pixel class such that every pixel in the blob is within a specified distance of some other pixel in the blob. Second, the invention contemplates allowing entities to consist of collections of several blobs from one or more pixel classes (rather than requiring every entity to consist of a single blob). The grouping of chromatic data points may involve obtaining a probability that the spatially connected subset is associated with a particular entity, and groupings may then be utilized to aid the system in assigning each of the chromatic data points to an entity.

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In the use of the invention to evolve a product algorithm, the results of the initial approximation or a subsequent approximation can be presented to the user for verification (See e.g., step 204 of Figure 2) via any type of user interface. In one embodiment of the invention a verification message is displayed to the user for purpose of obtaining input from the user that reflects the user's judgment about the accuracy of a classification. The verification message is transmitted to the user via any viable data path and may be sent to users in remote locations via an interconnection fabric such as a computer network. Upon receipt of the verification message, the user makes a judgment about the correctness of the classification. For instance, the user may acknowledge the correctness of the identification or indicate that a portion of the image the system identified as a certain type of entity is an entity of a different type. The data collected from the user during this process is stored and utilized in accordance with one embodiment of the invention for subsequent analysis of the image. Over time the system learns from obtaining feedback from the user and thus the ability of the system to properly identify, classify, and count the number of entities in the image improves.

For instance, at step 204, the system may present the initial identification to the user for feedback as to the classifications made and use that feedback as input to another iteration of the entity identification step 202 illustrated in Figure 2. The system may execute multiple iterations of this loop until the user indicates a desire to lock the evolving algorithm used to identify the entities in place and thereby commit an instance of the algorithm to memory (see e.g., step 205). When an evolving algorithm is locked

that algorithm can now be referred to as a product algorithm (or an instance of an evolving algorithm) and can be applied to different images or set of images by different users than the user responsible for training the algorithm (see e.g., step 206). However, the reader should note that the product algorithm essentially a saved instance of the evolving algorithm and that like the evolving algorithm it may also be permitted to evolve. In some instances, such evolution may not be desirable. This is particularly the case when an expert at a particular type of image classification was involved in training the product algorithm and the ultimate user of the product algorithm is a novice at identifying such classifications.

The system may store any of the data collected during the image analysis and use that data to aid subsequent analysis. Image data, user data, verification data, probability data, and any other information collected during evaluation of the image can be stored in a data repository and later utilized. Previous results obtained from the data repository can be used to determine probabilities. Such stored data is referred to in one embodiment as the product algorithm, although generally speaking the evolving algorithm may also utilize the stored data in any manner deemed helpful to the image analysis. Both the evolving algorithm and the product algorithm are capable of using the learned ability to classify a particular type of entity to generate a result that comprises an approximation of the total number of entities in the image (e.g., step 207).

Neural Network Overview:

Embodiments of the invention may be configured to additionally process the acquired image data using a neural network engine. Figure 5 illustrates a high-level view of the methodology for processing image data using a neural network engine in accordance with one embodiment of the invention. The neural network engine comprises a neural network and may optionally contain preprocessing functionality capable of preparing data for processing by the neural network engine. The preprocessing functionality may be contained within the neural network engine or part of another module that interfaces with the neural network engine.

For example, the system may obtain an image having many different chromatic data points (e.g., step 500), identify which of the chromatic data points comprise an entity (e.g., step 502 which may occurs via user input or automatically by the system via a classification algorithm), group the chromatic data points into one or more spatially connected subsets (e.g., step 504 which may group portions of the image together that fall with a certain color distribution), and determine a plurality of characteristics about each of the spatially connected subsets (e.g., step 506). These characteristics may then be passed to a classification engine for processing (e.g., step 508). The classification engine utilizes the characteristics of the spatially connected subsets to classify each of the spatially connected subsets into a classification (e.g., step 510). Some spatially connected subsets are assigned to a first class identifying the entity as a certain type and other spatially connected subsets may be assigned to a second class. In one embodiment

of the invention the classification engine utilizes Bayes' Theorem as the basis for determining the appropriate classifications. Subsequent (or previous) evaluations of the image data may occur using Fourier Shape Descriptors and/or a neural network. The determination made by the classification engine is then presented to the user for affirmation as to the veracity of the classification (e.g., step 512). Feedback (513) obtained from the user at this point can be used as input to one or more subsequent iterations of the classification engine. Optionally, the system may elect to pass a subset of the classification data to a neural network classifier engine (e.g., step 514).

The neural network classifier comprises a system of program and data structures designed to approximate the operation of the human brain. The neural network classifier may contain a large number of processors operating in parallel where each processor has a sphere of knowledge it understands. The classification data and/or other input are utilized to train the neural network and thereby increase the network's sphere of knowledge. The subset of data passed to the neural network in one embodiment of the invention is derived according to criteria defined by a user or users. The spatially connected subset is then evaluated to derive a set of relative harmonic amplitudes (e.g., step 516). The relative harmonic amplitudes may also be performed independently of the neural network engine. A fast Fourier transform calculation may be used to derive each relative harmonic amplitude. When a spatially connected subset is passed to a neural network classifier engine, the perimeter of the spatially connected subset is traversed counterclockwise and an *N*-point boundary of it is extracted. Then, a discrete Fourier

transform algorithm is applied to the *N*-point boundary to calculate pairs of harmonic amplitudes, $|z_{-n}|$ and $|z_n|$ for n = 1, 2, …,*N*. typically focuses only on $|z_{-n}|$ and $|z_n|$ for n = 1, 2, …, 10. Each of these 20 harmonic amplitudes is divided by the largest amplitude of these 20 amplitudes to yield a relative harmonic amplitude.

$$|z_n'| = \frac{|z_n|}{M}, \text{ where } M = \max\{|z_k| \mid k = \pm 1, \pm 2, \ldots, \pm 10\}.$$

Specifically, in one embodiment of the invention, the relative amplitudes of the low-order 20 Fourier shape descriptors of the boundary of the spatially connected subset are computed. These 20 values may be referred to as harmonic amplitudes. These 20 harmonic amplitudes are submitted as input to the neural network, which uses them to classify the connected subset as a specific type of entity. The reader should note, however, that more or less than 20 harmonic amplitudes may be utilized and that the ultimate number utilized depends upon the size and complexity of the image begin analyzed. Some embodiments of the invention may utilize other shape descriptors to define boundaries. Thus, the invention is not limited to the use of low-order Fourier shape descriptors, but can use any shape descriptor capable of defining boundaries.

Submit relative harmonic amplitudes to the neural network (e.g., at step 518). More specifically, for example, each blob (e.g., spatially connected subset) generates a corresponding vector of 20 relative harmonic amplitudes. These 20 relative harmonic amplitudes can be provided to the neural network as input at step 518. The neural

network, configured in accordance with one embodiment of the invention is trained to classify the spatially connected subsets using shape information provided by the set of relative harmonic amplitudes (e.g., step 520). The results of the classification performed by the neural network can then be optionally presented to the user for verification (e.g., step 522). The neural network may then utilize the user feedback (524) to adjust its analysis in accordance with the input obtained from the user. Thus, the input can be utilized as training criteria and used to improve performance of the image analysis over time. Once the entity classification engine and/or the neural network engine are deemed by the user to be appropriately trained, the user may elect to lock the algorithms generated by classifying a particular type of entity into place for subsequent use on the same or another set of images (see e.g., step 523).

The neural network in one embodiment of the invention comprises one input layer, two hidden layers and one output layer. The input layer may comprise, for example, 20 input neurons and one bias input neuron (although there may be more or less input neuron or bias input neurons). Each hidden layer comprises 16 hidden neurons, and the output layer comprises 5 output neurons (although there may be more or less hidden neurons or output neurons). This is a fully connected feed-forward network with three layers of adaptive weights. Networks having three layers of weights can generate arbitrary decision regions, which may be non-convex and disjoint.

The neural network accepts a number of relative harmonic amplitudes associated with a spatially connected subset (e.g., 20 although the number may differ depending upon the size of the image). Each output neuron corresponds to a specific class of entity. The outputs of all output neurons are compared, and then, the index of the output neuron that gives the largest value is returned as the class of the spatially connected subset whose relative harmonic amplitudes were presented to the input layer.

Although the neural network is pre-trained, the user can train the network through back-propagation as the user indicates a correct classification to the network. The user also can save the trained network for later use.

System Components:

Figure 11 illustrates the components incorporated within the system and input provided to the system in accordance with one embodiment of the invention. User input 1106 may be provided to a classification engine 1108, neural network engine 1112 or to other engines or modules 1114 configured to enhance or add functionality to the system. Classification engine 1108 may be involve manual input from the user (e.g., a sample set) or automatically obtain input from the image. In one embodiment of the invention, Classification engine 1108 classifies based on color or some other measure such as texture and provides such data to image processing application 1102 which utilizes at least one of the image processing methodologies described herein to generate classified image 1110. For instance, the image processing application may utilize multiple

iterations of Bayesian processing and/or may also use multiple iterations of processing performed by the neural network engine 1112. Such processing enables image-processing application 1102 to continually evolve and improve over time as the number of images (or amount of information) it reviews increases. After performing the methodology described herein, neural network engine 1112 may perform some level of classification (e.g., 1118) on identified spatially connected subsets and can therefore output the number of entities (e.g., objects) in spatially connected subsets (e.g., blobs) (e.g., 1116). This data may be utilized by the image processing application in some instances. Attributes (e.g., color, texture, radius, size, proximity to other entities, or any other useful descriptive feature, etc…) of classified image data 1110 are typically stored in image evaluation database 1120. The information stored in the image evaluation database 1120 can be referred to as the product algorithm. The attributes or stored values are loaded into a database 1104 (e.g., a neuropathology database) and the information may be utilized to derive prior probabilities 1105 that can be used by the image processing application for subsequent analysis of the same or different images. Such aggregate image data can be made available to other scientists to verify patient diagnosis, aid in the selection of samples for further research purposes etc… In addition entities may be compared with other non-visual data (e.g., genetic information, demographics, sex, disease presence, disease subtype, severity of the disease, subtypes of individuals including race, disease severity, prior medical history, genetic profiles). Entities can also be compared to data sets derived from similar sources containing genetic profiles of individuals (e.g., gene fingerprints). For example, the fine features of neuropathology can

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be effected by gene mutations, age itself, sex, etc… and thus could constitute a distinct feature of an evolving algorithm.

The image data itself is typically held in raw image database 1100, although image data or any of the other information stored by the system may be held in any type of memory medium that allows such data to be retrieved. Image data 1100 is what is initially provided to the user and/or system for evaluation.

Specific Modes of Operation:

Now that a brief overview of the processes and components utilized by an embodiment of the invention has been described, a more detailed discussion of the modes of operation will follow. Figure 6 illustrates the process of selecting and initiating a user mode in accordance with one embodiment of the invention. When a computer program or system incorporating aspects of the invention initiates, the user may select a user mode (600). If the user selects automated user mode 602, the system loads predefined pixel zoo database 604 and predefined entity zoo database 606 from data storage 612 (the data in the pixel zoo and entity zoo determines a product algorithm). The user then selects a set of images to process (608) and initiates processing (610) of the image data. The specific details associated with that processing and the contents of the databases referred to above are described in more detail in Figure 8. Subsequent to processing the image data may be stored in data storage 612.

If the user selects the independent user mode 614, the system captures a new image or loads an image set 616. The pixel zoo and entity zoo determining a product algorithm are then defined (e.g., 618) using a recursive series of processing techniques described in further detail in Figure 9. Once the user is satisfied with the result, the product algorithm can be stored at step 620, the data defining the pixel zoo and entity zoo can be stored in data storage 612, but may also be stored in other locations where the data contained therein can be retrieved for subsequent usage during image processing of the same or different image. Data storage 612 may also contain the image data itself, but like the zoo data, image data may be stored in any location where it can be retrieved.

Figure 7 comprises a block diagram illustrating the various user modes in accordance with an embodiment of the invention. For example, the system 720 may operate in an automated user mode 700 and an independent user mode 702. The system may operate in one or more of these modes. In automated user mode 700, the system operates automatically to classify the input image with no user intervention required (however, the user may provide input if such input is desirable). When the system is in automated user mode 700 the system takes as primary input one or more images and produces a set of classified images. In one embodiment of the invention, the data stored in the pixel zoo and entity zoo is utilized in automated user mode 700 as a classification aid.

In independent user mode 702 the system is trained to perform classifications in accordance with feedback provided by an independent user. The purpose of operation in

independent user mode is to produce tools (e.g., a product or evolving algorithm) that can be used to classify new images supplied to the system in automatic mode. If biological tissue samples are to be analyzed, the independent user may represent a trained histologist or some other user with an expertise in the nuances of evaluating biological tissues. The reader should note that although images of biological tissue samples are used as examples herein, the invention is not limited to analysis of such images. The system embodying the invention may be adapted to evaluate any type of image to classify an object and/or other entity contained in the image. When in independent user mode 702 one embodiment of the invention obtains image data from a repository of images. The output produced in independent user mode may comprise (1) a pixel zoo (e.g., samples of pixel-measure vectors representative of the various different pixel classes in the image); (2) a set of pixel class definitions, where each definition comprises a vector of parameters enabling the system to compute for new pixel chromaticities (e.g., chromatic data points), the probabilities that each pixel belongs to a different pixel classes; (3) an entity zoo (e.g., a collection of images of various different types of possible entities or objects), and (4) a set of entity definitions where each entity definition represents a vector of parameters enabling the system to compute for new entities the probabilities the entity belongs to the various different entity classes. The output generated in independent user mode can be stored and utilized for subsequent processing of other images.

The system's efficacy in automated user mode 700 depends in large part on the expertise the system acquires when operated in independent user mode 702. However, the description of independent user mode is easier to understand once the reader is clear how automated user mode 700 operates. Accordingly, automated user mode 700 is described in detail first. In addition there may be an interactive training mode 704 which can be used to train users how to identify entities. For instance, novice users may utilize the system to learn how to mimic the identification abilities of an expert. Thus the system may present entities previously classified by an expert so that the novice user may gain an understanding of what type of entities fall within which type of classification.

Automated User Mode Operation:

A. Image Acquisition:

As was mentioned above, the first step for performing processing on image data is to capture or load the image data (see e.g., Figure 8, block 800). For instance, if biological tissue data is to be processed, the system will obtain a digitized image *I* of a tissue sample. The input image *I* may be loaded from a database or captured directly from a slide using a microscope and CCD camera. To each pixel location (x,y) in the image field, the input image *I* assigns an *m*-tuple $I[x,y] = (\lambda_1[x,y], \lambda_2[x,y],\ldots, \lambda_m[x,y])$ of light spectral measurements. For human vision, three measurements are typically sufficient to completely represent any color. For this reason, standard CCD cameras and scanning equipment are designed to collect three light spectral measurements per pixel.

However, it should be noted that a machine vision application of the sort described herein might well take useful advantage of a potentially richer, higher than 3-dimensional chromatic image representation.

B. Pixel classification:

The system embodying the invention proceeds to assign each pixel in the Input Image *I* to one of several possible *pixel classes* (see e.g., Figure 8, block 804) which reflect the different general types of material to which that pixel might belong. For example, in a single labeled biological section, two classes are likely to be present: positively labeled entities (densely stained) and the background (weakly stained, or unstained). In double-labeled biological tissue sections, three classes are likely to be present: the primary entities – labeled with one stain, and the secondary entities – labeled with the other stain, and the background. The system can use arbitrary numbers of pixel classes, depending on the chromagens used, and the ways in which different types of biological material interact with them. In the general case, each pixel will be assigned to one of the pixel classes c_0, c_1,..., c_n, where c_0 conventionally denotes the "background" class, and each of the classes c_i, i = 1, 2,…, n, corresponds to a particular type of spectrally and/or texturally distinct histological material of interest.

A Bayesian classifier is used in one embodiment of the invention to assign pixels to different classes. The user may select a *pixel zoo* database 806 previously produced 808 by using the system in Independent User Mode. The data held in *pixel zoo* database

806 is also referred to in accordance with one or more embodiments of the invention as a product algorithm. This pixel zoo comprises representative samples S_i of *pixel-measure* vectors $v = (v_1, v_2,\ldots, v_r)$ from each pixel class, c_i, i = 0, 1,..., n. The coordinate values in the pixel-measure vector $v[x, y] = (v_1[x,y], v_2[x,y],\ldots, v_s[x,y])$ corresponding to a particular pixel (x, y) typically include the light spectral values, $\lambda_1[x,y]$, $\lambda_2[x,y]$,..., $\lambda_m[x,y]$, assigned to pixel (x,y) in the input image, but may also include additional (context-sensitive) statistics reflecting aspects of the configuration of light spectral values assigned to other pixels in the neighborhood of (x, y). Such additional statistics can provide the pixel classification process with sensitivity to textural properties of image material. Typically, the pixel zoo supplied by the user will have been extracted from one or more images whose preparation history is identical or similar to that of the current image(s). Also stored in the pixel zoo are the following parameters, derived from the samples S_i:

I. *Estimated pixel class prior probabilities.* For each pixel class c_i, the prior probability $p[c_i]$ is the proportion of pixels in the current image that the system expects (based on previous experience) to belong to class c_i.

II. *Estimated pixel class definitions.* Associated with each pixel class c_i is a conditional probability density $f(v|c_i)$. For any possible pixel-measure vector v,

and any pixel class c_i, $f(v|c_i)$ gives the probability density that a pixel in class c_i will have pixel-measure vector v. That is, for any pixel (x,y), $f(v|c_i)$ is the probability density that $I[x,y] = v$, given that pixel (x,y) is in class c_i. The *definition of pixel class* c_i is a parametric approximation of $f(v|c_i)$ derived from the sample S_i (e.g., using a modified Expectation Minimization (EM) algorithm). The EM algorithm is modified in one embodiment of the invention so that it updates its parameters after each observation of one new data point. The algorithm generates a mixture of Gaussian probability density functions. Each Gaussian function, called an "expert" in one embodiment of the invention, accounts for a subset of data points. After each observation of a new data point, the algorithm can add, if necessary, an expert to a mixture of experts, which generates the probability density function covering the set of data points given thus far. It also can delete an expert when the expert is found unnecessary after each observation. After all the data points are observed, the algorithm updates the parameters in a batch mode in order to merge down experts, whose fields have a large overlap. As a result, the number of necessary experts is automatically determined and satisfactorily optimized. The term expert should not be confused with expert user that specifically involves human input.

Given (i) the *a priori* probability $p[c_i]$ that any given pixel (x,y) belongs to class c_i, and (ii) the conditional probability density $f(v|c_i)$ that a pixel in class c_i is

assigned pixel-measure vector *v*, Bayes' Theorem is now used to compute the posterior probability (See e.g., Figure 8, Box 802),

$$P_i[x,y] = p_{posterior}[c_i \mid v[x,y]] = \frac{p[c_i]f(v[x,y] \mid c_i)}{\sum_{k=1}^{n} p[c_k]f(v[x,y] \mid c_k)}. \quad (1)$$

$P_i[x,y]$ gives the probability, based on prior knowledge and current information, that pixel (x,y) is contained in class c_i.

Each pixel (x,y) is now assigned to the class c_i for which $P_i[x,y]$ is maximal (see e.g., Figure 8, Box 804). In one embodiment of the invention these assignments are displayed in a separate window so the user can compare these classifications with the original image to verify system performance. After all pixels have been assigned to pixel classes, the system embodying the invention may proceed to the *Entity Classification* (e.g., stage B) of processing.

C. Entity Classification

When the system is used in Automated User mode, its goal is to assign each pixel in the image to a particular type of entity (e.g., a histological structure) based not just on color but other features of the entity as well, such as shape, texture, size, etc. The assignment of pixels to distinct pixel classes is one of the steps toward this end. In the next stage of processing, the system (i) groups pixels within a given pixel class into

"blobs," (i.e., maximal, spatially connected subsets) and then (ii) uses yet another stage of Bayesian processing, this time based on blob morphology, to assign each blob to its most probable entity class.

1. *Partitioning pixel classes into blobs (e.g., maximal spatially connected subsets)*:

The first step in entity classification is to partition each pixel class c_i into maximal, spatially connected subsets (i.e., *blobs*) of pixels (see e.g., Figure 8, block 810). A set B of pixels is *connected* in class c_i if $B \subset c_i$, and any pixel in B can be reached from any other pixel in B by a sequence of single-pixel, vertical or horizontal steps without leaving B. B is *maximal* if there is no strict superset of B that is connected in c_i. In practice, one "grows" blobs by (i) initializing the new blob to be a pixel in class c_i that has not yet been included in any maximal blob, and then (ii) recursively including in the new blob any pixel in c_i that is horizontally or vertically adjacent to some pixel that has already been included in the new blob.

2. Application of blob (maximal, spatially connected subset) measures:

To each such subset B (called a *blob*) the system now applies a battery of morphologically sensitive functions, $\phi_1, \phi_2, \ldots, \phi_q$, called *blob measures (e.g., at block*

812). A *blob measure* is a function whose value depends on the pattern of pixel values within, or in the neighborhood of, the given blob. Some examples of blob measures are

- the total number of pixels composing the blob
- the length of the blob's boundary divided by the total number of pixels in the blob.
- the mean level of chromatic measure $\lambda_i(x,y)$ over all pixels (x,y) within the blob. (Note that to compute this measure requires access to the chromatic information in the original image)
- the total number of pixels assigned to pixel class c_j that lie within a distance of 20 pixels of the blob. (Note that to compute this measure requires access to the values of pixels outside the blob).

For a given pixel class c_i, there may be various types of entity structure (e.g., cellular structure) that might actually have produced a c_i blob *B*. Let us denote these different possible entities as $o_{i,0}$, $o_{i,1}$, $o_{i,2}$,..., $o_{i,r(i)}$. Thus, there are r(i)+1 different possible types of entities that can be composed of pixels in pixel class c_i. As a matter of convention, the system may let $o_{i,0}$ designate the class of "nonentities" (amalgams of c_i detritus that do not merit classification as any particular sort of entity).

3. Bayesian blob classification

As described above, a Bayesian classifier is used to assign pixels to pixel classes; the assignment of blobs to entity classes proceeds similarly (e.g., at step 814). In one

embodiment of the invention there are, however, important differences between the blob vs. pixel classification stages. The user is first prompted to supply the name of an entity *Zoo 816*. This Entity Zoo comprises representative samples $T_{i,j}$ of blobs from each entity class, $o_{i,j}$, i = 0, 1,…, n; j = 0, 1,…, r[i]. (i.e., $T_{1,1}$ is a set containing many examples of blobs from pixel class c_1 that belong to entity class $o_{1,1}$). Also stored in the Entity Zoo are various parameters derived from the samples $T_{1,1}$.

It should be noted that these samples $T_{1,1}$ may well comprise blobs that have been obtained in the past from a range of different tissue images (e.g., images from different parts of the brain, from different patients showing different symptoms). In this respect, the Entity Zoo is likely to differ from the pixel zoo. The point here is that one expects pixel color to depend on the particular staining history of a given sample. However, the morphology of a particular histological structure of interest is likely to be largely invariant with respect to changes in the source of the image being analyzed. However, what is likely to vary systematically as a function of changes in image source is the *prior probability* of finding different varieties of entities.

I. <u>*Estimated entity class prior probabilities.*</u> For each entity class $o_{1,1}$, the prior probability $p[o_{1,1}]$ is the proportion of c_1 blobs in the current image that the system expects (based on previous experience) to belong to class $o_{1,1}$. Such factors as brain region of sample, genetic information, demographics, sex, disease presence, disease subtype, subtype of individual (including race), disease severity,

prior medical history, etc. are used (e.g., in the context of a general linear model) to estimate $p[o_{i,j}]$ from the entity zoo. In addition entities may be compared with other non-visual data (e.g., genetic information, demographics, sex, disease presence, disease subtype, severity of the disease, subtypes of individuals including race, disease severity, prior medical history, genetic profiles). Entities can also be compared to data sets derived from similar sources containing genetic profiles of individuals (e.g., gene fingerprints).

II. *Estimated entity class definitions.* Suppose our blob measures are $\phi_1, \phi_2, \ldots, \phi_q$, and define the vector-valued function of ϕ of blob-measures by

$$\phi(B) = (\phi_1(B), \phi_2(B), \ldots, \phi_q(B)) \qquad (2)$$

for any c_i blob B. Associated with each entity class $o_{i,j}$ is a conditional probability density $f(w| o_{i,j})$. For any blob-measure vector w, $f(w| o_{i,j})$ gives the probability density that a blob in class $o_{i,j}$ will have blob-measure vector w. That is, for any c_i blob B, $f(w| o_{i,j})$ is the probability density that $\phi(B) = w$, given that B is in entity class $o_{i,j}$. The *definition of entity class* $o_{i,j}$ is a parametric approximation of $f(w| o_{i,j})$ derived from the sample $T_{i,j}$.

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Given (i) the *a priori* probability $p[o_{i,j}]$ that a given c_i blob belongs to class $o_{i,j}$, and (ii) the conditional probability density $f(w|o_{i,j})$ that a blob in class $o_{i,j}$ is assigned blob-measure vector w, Bayes' Theorem is now used for each c_i blob B to compute the posterior probability (see e.g., figure 2, block 814),

$$P_{i,j}[B] = \frac{p[o_{i,j}]f(\phi(B)\,|\,o_{i,j})}{\sum_{k=0}^{r[i]} p[o_{i,k}]f(\phi(B)\,|\,o_{i,k})} \qquad (3)$$

Given our previous knowledge, and the results of applying the vector-valued function of blob measures to B, $P_{i,j}[B]$ gives the probability that B is actually an entity of type $o_{i,j}$. We now assign B to whichever entity class, $o_{i,j}$, j = 0, 1,…, r(i), it most probably belongs.

In one embodiment of the invention, the classified image is now returned as output (e.g., step 820). In other embodiments of the invention, the blob classifications achieved in this stage of processing are treated as tentative, rather than final, and are channeled into a second phase of pixel-classification in which the original assignments of pixels to different classes are subject to revision in light of the tentative entity classifications. The output from this second stage of pixel classification is then submitted to another stage of blob-classification. This process may recur several times before a final classification is returned.

Independent User Mode Operation:

When the system embodying the invention is used in Automated User mode, the input is a digitized image, and the output is an image containing blobs that have been classified as various sorts of histological entities. Before the system can be operated in Automated User mode, however, the pixel classes, c_i , i = 0, 1,…, n, and entity classes $o_{i,j}$, i = 1, 2,…, n; j = 0, 1,…, r(i), should be defined. In one embodiment of the invention, defining the pixel and entity classes (e.g., building a product or evolving algorithm) is the purpose of operating the system in Independent User Mode. Figure 9 illustrates the processes associated with the independent user mode in accordance with one embodiment of the invention. Input for the independent user mode is typically retrieved interactively from an archive of digitized images (e.g., 900) specified by the user. Output comprises:

(1) a *Pixel Zoo* (e.g., 918) comprising representative samples S_i, i = 0, 1,…, n, of pixel-measure vectors from each pixel class,

(2) *Pixel class Definitions* based on the pixel zoo samples (e.g., 901) S_i, (i.e., parametric estimates of the conditional densities $f(v|c_i)$ of obtaining pixel-measure vector v, given that v is generated by a pixel in pixel class c_i),

(3) an *Entity Zoo* (e.g., 919) comprising many representative samples $T_{i,j}$ of blobs from each entity class, and

(4) *Entity Class Definitions* based on the entity zoo samples $T_{i,j}$ (i.e., parametric estimates of the conditional densities $f(w|c_{i,j})$ that $\phi(B) = w$, given that B is an entity of type $o_{i,j}$).

A. Pixel Zoo generation:

After having obtained a new digitized, tissue sample image (e.g., at block 900, which executes as described above with respect to block 800 of Figure 8). The system configured in accordance with one embodiment of the invention prompts the user to either (i) provide a sample S_i of pixels belonging to each of the classes c_i, i = 0, 1,…, n (where n is specified by the user), or else to (ii) read in the parameters defining conditional densities, $f(v|c_i)$, which have been previously obtained from a similar tissue sample and stored along with an associated pixel zoo (e.g., 901).

If it is necessary to estimate conditional densities $f(v|c_i)$ from the current sample, the system may obtain a sample set as follows: For a given class c_i, the user selects the required S_i by mouse-clicking several regions of the image filled with pixels from class c_i (e.g., at block 902). The sample S_i may be referred to as the *zoo sample of pixel class i.*

The system may use a flood-fill procedure to grab all pixels in the neighborhood of the mouse-clicked pixel whose pixel-measure vectors are similar to the pixel-measure vector of the clicked pixel, at the same time showing the user exactly which pixels have been included in the sample. Alternatively, an eyedropper procedure may be used to add individual pixels to the sample S_i.

After zoo samples (e.g., a sample set) have been collected for each pixel class, The system estimates the conditional densities $f(v|c_i)$, i = 0, 1,…, n from the obtained samples (e.g., at block 904).

If the pixel classes being defined in the current application of the system are completely new, then prior probabilities $p[c_i]$, i = 0, 1,…, n are taken (by default in one embodiment of the invention) to be uniform: i.e., $p[c_i] = \frac{1}{n+1}$, i = 0, 1,…, n. Typically, however, previously classified images will be available from which it is appropriate to derive estimates of prior probabilities. This will be the case, for example, when the previous images are of the same type of tissue as the current images, and are stained with the same combination of chromogens as was used for current images. If the only differences between the current image and previously classified images involve depth of staining, for example, then pixel classes in the current sample are expected to be generated by the same types of histological entities as were the pixel classes in the previous samples. In this case, the user can supply the name of the image archive from

which priors are to be estimated. Prior probabilities are then estimated by setting $p[c_i]$ equal to the proportion of pixels in the specified image population that were assigned to class c_i.

The system proceeds to apply Eq. (1) to the pixel-measure vectors of pixels in the current image (e.g., at block 906), and to assign each pixel to its most probable pixel class (e.g., at block 908). The classified image is now presented, (e.g., side by side) with the original, so that the user can check that the classification is correct (e.g., at block 910). If the classification is incorrect or has room for improvement in the opinion of the user (e.g., at block 912), the user provides feedback to the system, indicating how misclassified pixels should have been classified (e.g., at block 914).

Based on this feedback, the system (1) moves misclassified pixels from their current pixel zoo samples to the correct samples, (2) revises its estimates of conditional densities $f(v|c_i)$, i = 0, 1,…, n (e.g., at block 916) in view of the feedback obtain from the user. The user also has the option of adjusting the estimates of prior probabilities to reflect the proportions of pixels assigned to the different pixel classes in the current image. However, if estimates of priors were originally based on a large sample of previously classified images, then the user may prefer to retain the current estimates without alteration (see e.g., at block 911).

Then the system applies Eq. (1) once again to every pixel value I[x,y] in the image (e.g., executes block 906), and once more assigns each pixel to its most likely

pixel class (e.g., block 908). Then the reclassified image is presented once more (e.g., side by side with the original) for the user to check veracity (e.g., block 910).

This process repeats until the user is satisfied with the classification. After the user has ratified the classification, the Pixel zoo Z_{pixels} is stored as output (e.g., 918). Z_{pixels} comprises

I. the samples S_i, i = 0, 1,…, n. (Each sample S_i contains many pixel-measure vectors belonging to pixel class c_i.)

II. the prior probability estimates, $p[c_i]$, i = 0, 1,…, n.

III. the estimated conditional densities $f(v|c_i)$, i = 0, 1,…, n.

Once the pixel zoo has been produced and stored, the system proceeds to Entity Zoo construction.

B. Entity Zoo construction and entity definition:

As when the system is operated in Automated User Mode, the image is now partitioned into blobs based on pixel class (e.g., at block 920), and for each blob B, $\phi(B)$ is computed (Eq. (2)) (e.g., at block 922).

1. Entity Zoo initialization:

The pixel-classified image is presented to the Independent user for feedback (e.g., side by side with the original, digitized image) (e.g., at block 912). Then for each pixel class c_i, the user begins by indicating ((e.g., at block 924) with mouse clicks or other input) several blobs (e.g., approximately 5 in one embodiment of the invention, but the system may use more or less) in entity class $o_{i,0}$, then several in class $o_{i,1}$, then several in class $o_{i,2}$, etc. successively for each entity class in pixel class c_i. (It may be that more than one image must be accessed in order to obtain a sufficient number of entity examples in each class.) Let $T_{i,j}$ be the sample of blobs selected by the Independent user as examples of entities belonging to class $o_{i,j}$ (e.g., at block 926).

In addition to initializing the entity zoo, the system may also need to initialize the *a priori* probabilities of different entity classes. For i = 1, 2,..., n; j = 0, 1, 2,..., r(i), the *a priori* probability $p[o_{i,j}]$ that a randomly chosen blob in pixel class c_i is actually an entity of type $o_{i,j}$ is initialized to the uniform distribution. That is, the system may initially set $p[o_{i,j}] = \frac{1}{r(i)+1}$.

2. Definition estimation:

Our target is an adequate estimate of the function $f(w|o_{i,j})$, which is called the *definition* of entity class $o_{i,j}$. For any blob B in pixel class o_i, $f(w|o_{i,j})$ gives the conditional probability density of the vector value $w = \phi(B)$, given that B is in class $o_{i,j}$.

The system can base a current estimate on the examples currently in the entity zoo, and iteratively refine this definition by adding new examples of different entities to appropriate entity zoo samples, $T_{i,j}$.

For each entity zoo sample $T_{i,j}$, i = 1, 2,…, n; j = 0, 1,…, r(i), The system computes the vector-valued function $\phi(B)$ of blob measures for each blob B assigned to $T_{i,j}$. This yields sample of (q-dimensional) points $w = \phi(B)$ that is now used as the basis for a parametric estimate of $f(w|o_{i,j})$ (which may be derived, for example, using a variant of the EM algorithm) (e.g., at block 928). The estimated function $f(w|o_{i,j})$ has the following porperties: (1) $f(w|o_{i,j})$ is non-negative for all $v \in \Re^q$, (2) the integral of $f(w|o_{i,j})$ over all $w \in \Re^q$ is equal to 1, and (3) $f(w|o_{i,j})$ takes high values in regions of $\Re^q$ containing values $\phi(B)$ for many blobs B assigned by the Independent user to class $T_{i,j}$, and low values elsewhere.

3. Entity classification (e.g., block 930)

Once the system has an estimate of the definition $f(w|o_{i,j})$ for each entity class $o_{i,j}$, these definitions are applied in the context of a Bayesian classification procedure in order to classify the blobs, either in the current image, or else in a new image.

For each c_i blob B in the current image, B is classified using Bayes' Theorem (Eq. (3)) to obtain for each entity class $o_{i,j}$ the posterior probability $P_{i,j}[B]$ that B is in class $o_{i,j}$. Given the systems previous knowledge, and the results of applying morphological

measures to B, $P_{i,j}[B]$ gives the probability that B is actually an entity of type $o_{i,j}$The system proceeds to assign B to whichever entity class, $o_{i,j}$, j = 0, 1,…, r(i), B most probably belongs.

4. User validation and zoo expansion

The classified image is presented to the user for feedback. For instance, the classified image can be presented with each blob color-coded to signal the entity class to which it has been tentatively assigned (e.g., at block 932). The user reclassifies any obviously misclassified blobs (e.g., at block 934) that he/she detects by selecting them with the mouse and indicating their proper classes. The blobs singled out by the user as having been misclassified are added to the correct entity zoo samples (e.g., at block 935).

If the Independent user judges that all of the remaining blobs in the image have been correctly classified, (e.g., at block 933) he/she can instruct the system to include all blobs in the entity zoo samples corresponding to the entity classes to which they have been assigned.

Alternatively, if many errors remain in the tentative classification produced by the system, the Independent user can select individual blobs for inclusion in one or another entity zoo sample.

Prior probabilities may now be recomputed. If the proportions of blobs included in the various entity zoo samples may be assumed to approximate the proportions in the

population at large, then the Independent user may instruct the system to base its new estimate of the prior probabilities on the updated zoo samples. In this case, one embodiment of the system uses a general linear model to estimate $p[o_{i,j}]$ as a function of the information associated with the current image (e.g., sex, diagnosis and age of death of patient, region of brain from which the sample was taken, etc.).

Alternatively, if the Independent user judges that the sizes of the entity zoo samples do not reflect the proportions of different types of entities in the population at large, the Independent user may opt to continue using the previous prior distribution.

5. Termination

The system iterates stages Definition estimation, Entity classification, and User validation and zoo expansion until the user terminates the process (typically, when the Independent user is satisfied that the system automatically classifies new entities correctly on the basis of the entity definitions derived from the entity zoo samples). At this point the system produces as output the entity zoo $Z_{entities}$. $Z_{entities}$ comprises

I. the samples $T_{i,j}$, i = 0, 1,…, n, j = 0, 1,…, r[i] (Each sample $T_{i,j}$ contains many blobs belonging to entity class $o_{i,j}$.) Associated with each blob in $T_{i,j}$ is all the information about the source of the tissue from which it was derived.)

II. the prior probability estimates, $p[o_{i,j}]$, i = 0, 1,..., n, j = 0, 1,..., r[i].

III. the estimated conditional densities $f(w|o_{i,j})$, i = 0, 1,..., n, j = 0, 1,..., r[i].

The pixel zoo (e.g., 918) and entity zoo (e.g., 936) output generated by the system in cooperation with feedback from the user is referred to in one embodiment of the invention as a product algorithm, and such output may be applied to multiple images likely to contain entities to be classified.

Neural Network Engine:

As mentioned above, the system may comprise a neural network engine configured to evaluate image data. The detailed aspects of the neural network engine and the functionality associated therewith will now be described in further detail. A specific instance of image processing (classifying histological structures in brain slices) is utilized for illustrative purposes. However, the same technique is applicable to processing and classifying any other type of image data.

The neural network is configured to classify entities in image data (e.g., histological structures such as senile plaques). In this instance the neural network utilizes Fourier shape descriptors of plaque entity boundaries as inputs, and is evolved via genetic algorithms, rather than trained (although it may be trained). When a spatially connected subset is presented, the neural network classifier engine traverses the perimeter of the spatially connected subset and derives relative harmonic amplitudes from the perimeter.

Then, the neural network classifier accepts the relative harmonic amplitudes and returns the index of the output neuron that gives the largest value as the classification result for the spatially connected subset. In one embodiment of the invention, the network is pre-trained through genetic algorithms with a small set of training data. The results are presented to the user so that the user can confirm each classification result, and if the classification is wrong, train the network through back-propagation by indicating the correct classification. The user also can save and load the network that he/she trained for his/her later use. Over time the systems ability to accurately classify entities in an image will improve. Embodiments of the invention utilize a set of one or more evolving algorithms linked together to analyze features of the image data based on the identification information provided by the user. For instance, the system may utilize the entity classification algorithms described above alone or in combination with the neural network engine.

Neural Network Image Processing Example:

A specific example of an embodiment of the invention implemented in computer software to isolate, classify, and count entities in digitized images of histological structures will now be described. The reader should note, however, that the same techniques may be utilized to process any type of image data comprising entities. In this example, each histological section has entities such as senile plaques or tangles and the invention provides a way to count the number of senile plaques and tangles in the

histological image. Histologists and the computer application often disagree when it comes to the classification of plaque-type entities, which are initially classified by pixel color (the way many current systems operate). The disagreement arises when it comes to deciding how many plaques the identified entity contains. The neural network classifier described herein narrows the gap between histologists and the computer application.

Given the image of a histological entity, the main task of the entity classifier is to tell if it is a single entity or multiple entity, and moreover, to determine how many overlapping sub-entities the entity is made of. For instance, the system executing an embodiment of the invention can distinguish single entities from multiple entities. Among a variety of measures suitable for this purpose, the shape information of an entity's perimeter helps determine how many entities are present or whether there is any overlap. The system may acquire this information in terms of Fourier descriptors of an entity's perimeter. The system may also be configured to acquire information such as an entities size, shape, color, texture, or other distinguishing features. Once the system obtains the information it may utilize for entity classification, it executes an algorithm to process that data that is stochastically robust. In one embodiment of the invention, the system passes feature information (e.g., relative harmonic amplitudes) to a neural network. A set of connection weights on the neural network is determined via genetic algorithms, which can effectively search a huge space so that a globally optimal, or nearly optimal, set of connection weights will be found.

Fourier Descriptors:

Fourier descriptors may be utilized to analyze the shape information of closed curves. Assume that $z(l)$ describes a closed curve in the complex plane, where $z(0)$ is a starting point that can be chosen arbitrarily and l is the length of the curve traced counterclockwise from the starting point. Further assume that L is the length of the whole curve so that $z(0) = z(nL)$ for any integer n. Then $z(l)$ can be represented as a series of complex exponentials.

$$\begin{aligned} z(l) &= \sum_{n=-\infty}^{+\infty} z_n e^{j\omega n l} \\ &= z_0 + \sum_{n=1}^{+\infty} \{ \underbrace{z_{-n} e^{-j\omega n l} + z_n e^{j\omega n l}}_{elli_n(l)} \}, \end{aligned}$$

where $\omega=2\pi/L$ and z_n, called an n-th *Fourier descriptor* or *harmonic element* for $n \in \{-\infty,...,0,...,\infty\}$ is a complex number. In this example, z_0 is the center of gravity of the curve; thus an embodiment of the system can ignore z_0 as it is typically uninformative about the shape of $z(l)$. Each term

$$z_{-n} e^{-j\omega n l} + z_n e^{j\omega n l}$$

describes an ellipse. Thus, a pair of Fourier descriptors, z_n and z_{-n} is called an *elliptic Fourier descriptor*. The ellipse, $elli_n(l)$, is covered n times while l changes from 0 to L.

As mentioned, z_n for $n \in \{-\infty,...,0,...,\infty\}$ is a complex number; thus,

$$z_n = \mathrm{Re}(z_n) + j \times \mathrm{Im}(z_n)$$
$$= |z_n| e^{j\Phi n},$$

where

$$\mathrm{Re}(z_n) = |z_n| \cos(\Phi_n), \quad \textit{and}$$
$$\mathrm{Im}(z_n) = |z_n| \sin(\Phi_n).$$

$|z_n|$ is called an *n*-th *harmonic amplitude*, and ϕ_n is an *n*-th *harmonic phase*. In each ellipse, $elli_n$, there are two harmonic amplitudes and phases, $|z_{-n}|$, $|z_n|$, ϕ_{-n}, and ϕ_n. In general, $|z_{-n}|$ and $|z_n|$ together determine the size of the ellipse. More precisely, the sum of these two values is the long radius of the ellipse, and the difference of these two is the short radius. On the other hand, ϕ_{-n} and ϕ_n determine the orientation of the ellipse.

In practice, Fourier descriptors are calculated by a discrete Fourier transform algorithm after extracting an *N*-point boundary, $\{z(kL/N)\}$, where *k* ranges from 0 to *N*—*1*. The larger *N* is, the more precise the Fourier descriptors become. The size of *N* may be dictated by time and memory constraints and N should therefore not be too large. It is also convenient to make *N* a power of two because fast Fourier transform algorithms can be effectively implemented in that case. Once the system obtains Fourier descriptors of a

given closed curve, the system can reconstruct the curve from its Fourier descriptors. The more descriptors the system use, the more closely the system can approximate the original curve. Figures 13, 14 and 14 are reconstructed outline curves of Figure 12 (element 1200). The difference among these three is the number of harmonics used. These closed curves (e.g., 1300, 1400, and 1500) may be described as

$$z'_k(l) = \sum_{n=1}^{k} elli_n(l),$$

where k =10 for Figure 13, k=20 for Figure 14, and k=30 for Figure 15. If the system uses only low order descriptors, the reconstruction of the curve tends to exclude fine detail.

Fourier Descriptors of Plaque-like Entities

Histological entities (e.g., cells, nuclei, neurons, astrocytes, senile plaques) often take very complicated, distorted shapes with ragged edges. However, the raggedness is usually indicative of noise the system can filter out and contributes primarily to higher order harmonic elements. Thus, for the pattern recognition of those entities, only the lower order harmonic elements are used in one embodiment of the invention. Moreover, harmonic amplitudes are typically more vital than harmonic phases. Harmonic phases are very sensitive to starting points, $z(0)$. Even if two entities are of the same shape and size, harmonic phases for one are different from those of the other if one entity is a rotated image of the other. However, harmonic amplitudes of the one are identical to those of the other under such conditions. Thus, an embodiment of the

invention focuses attention on harmonic amplitudes although the use of harmonic phases may be justified by considering the shifts of phases relative to ϕ_1, i.e., $\phi_n - \phi_1$,.

If the system is solely interested in the shapes of the entities, the system can further simplify the matter. As mentioned earlier, $|z_{-n}|$ and $|z_n|$ together determine the size of the ellipse, $elli_n$ (l). In fact, $|z_{-1}|$ and $|z_1|$ together usually give a rough estimate of entity size.

However, the information of entity size is obtained in one embodiment of the invention by counting pixels. Thus, by making all $|z_n|$'s relative to the largest one, the system can simplify the neural network entity classifier. Some merits of this conversion are that the magnification scale of images becomes less important and an optimal set of connection weights becomes easier to obtain because the neural network classifier may work with input values from the restricted domain, [0,1].

Figures 17 and 19 show relative descriptor amplitudes of plaque (e.g., entity 1600 & 1800) samples shown in Figure 16 and 18, respectively. Top rows A show $|z_n|$, bottom rows B show $|z_{-n}|$, and n ranges from 1 to 30 from left to right. In both cases, $|z_1|$ is the largest amplitude, and all other amplitudes are made relative to it.

These Figures illustrate that in one embodiment of the invention only lower order harmonic amplitudes make any significant contribution to the shapes. Second, Figures 17

& 19 contain useful information to help distinguish these two shapes. Note in particular that both $|z_{-1}|$ and $|z_3|$ are substantially larger in Figure 19 than in Figure 17. Indeed, this is usually true when the system compares a double plaque entity to a single plaque entity. $|z_3|$ tends to be larger when a shape is elongated rather than circular, and $|z_{-1}|$ tends to be larger for shapes that deviate from ellipses by being pinched on opposite sides. Such shapes are marked by opposing concavities such as are evident in Figure 18.

Identifying entities that are made of three or more overlapping plaques is not this easy. Because there are so many topological variations in their shapes, two entities in different classes may happen to take a similar shape. Even though they are different to our eyes, they may show a similar spectrum of harmonic amplitudes. Figure 21 shows the descriptor amplitudes (A, B) obtained from the plaque image (2000) in Figure 20.

Another problem is that higher order harmonics will contribute to the shapes of compound plaques. Those higher order harmonics may be considered as noise, and thus ignored mistakenly. As a result, those entities may be misclassified. However, note that their descriptor amplitudes are still clearly different from descriptor amplitudes of single plaques as is evident from Figures 17 and 21. Therefore, the system can easily distinguish them from single plaques.

Neural Network Entity Classifier:

A neural network may be utilized to aid the system in allowing a set of connection weights evolve by genetic algorithms, rather than training such connection weights by back propagation. Genetic algorithms can search a huge space for globally optimal, or nearly optimal, solutions. By contrast, back propagation is a *hill-climbing* training method, which is simple, straightforward, but likely to get stuck with a locally optimal set of connection weights.

Genetic algorithms are search algorithms based on natural selection. They maintain a population of individuals $P(t)=\{x_{1,t}, \ldots, x_{n,t}\}$ for generation t. Each $x_{i,t}$ represents a potential solution to a given problem. Each potential solution is evaluated to give some measure of its fitness. Then, the new population $P(t+1)$ is formed by selecting the fitter potential solutions from $P(t)$. Some new individuals undergo transformations by genetic operators, such as mutation and crossover. After some number of generations, the population converges such that the best individual in the population represents a nearly optimum solution.

In a typical feed-forward neural network, an input to a neuron, except to input neurons, is a weighted sum of all outputs from the neurons on the previous layer. Those weights are called connection weights. These parameters determine the behavior of the neural network.

Genetic Algorithm for Neural Network

Genetic algorithms typically utilize a simple data representation which is commonly referred to as a *chromosome*, and to which genetic operations, such as mutation and crossover, can be applied. In this approach, each connection weight is represented in a 32 bit long vector (although other bits lengths may be utilized). With this 32 bit long vector, the system represent a real number ranging from -128 to +128 with 2^{-24} step width, to narrow down the search space for practicality. All connection weights are concatenated so that they form a chromosome which is actually a long bit vector. The number of input, output, and hidden layer neurons are fixed in our approach; therefore, each chromosome is a bit vector of fixed length. Mutation is a random change on a randomly chosen bit of a chromosome, and crossover between two chromosomes is an exchange of corresponding bits from a randomly chosen crossover point to the end of the chromosomes.

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Fitness Function

Selection by fitness is an essential part of genetic algorithms. The selection process evaluates the fitness of each chromosome, sort chromosomes by fitness, discard the bottom half of them, and duplicate the rest.

On the other hand, fitness functions typically require some elaboration in order to make a genetic search work. The system is configured to find a set of connection weights with which the neural network classifier can classify entities as correctly as possible. However, accuracy alone is hardly a sufficient fitness criterion.

Consider the following fictitious situations. If it is sunny in Southern California, say 85% of the year, every weatherman can claim that his weather forecast is 85% accurate. All that a weatherman has to do is always to say that it will be sunny tomorrow. He needs to make no calculation or analysis to produce his forecast. However, he will not be able to get a job as a weather man in San Francisco or Seattle.

A similar situation may occur in entity classification problems. For example, the majority of plaque entities to be classified happen to be single plaques. Under such a condition, the neural network classifier may evolve itself to classify every plaque entity as a single plaque if accuracy is the only criterion to measure the fitness of a set of connection weights. When the system uses classification accuracy as the only criterion to measure fitness this can occur.

One solution for this is to make the base data set for fitness evaluation comprise equal numbers of entities from all classes, and randomly select the data set for fitness evaluation from the base set every time the fitness of a chromosome is measured. This not only prevents the classifier from becoming over-fit to a particular data set, but also makes the algorithms as fool-proof as possible. Though this strategy alleviates the symptom, it is still possible to overlook a chromosome that results in a *cheater* neural network.

To reduce the likelihood of evolving cheater networks, the system introduces an additional heuristic for fitness evaluation. Specifically, the system measures the Euclidean distance between the probability distribution of plaque entities in a data set for fitness evaluation and the probability distribution of the outputs from the neural network with a given chromosome.

$$\|d_t - d_o\| = \sqrt{\frac{\sum_{i=1}^{k}(d_t(i) - d_o(i))^2}{k}},$$

where k is the number of different plaque classes, and for $i = 1,2,\ldots,k$, $d_t(i)$ gives the proportion of plaque images in the test data set belonging to class i, and $d_o(i)$ gives the proportion of images assigned to class i by the network. Since the test data set is randomly chosen for each fitness evaluation, this heuristic gives us a measure of how honestly the neural network with a given chromosome does its job.

The actual fitness of each chromosome is given by the equation:

$$fitness = error\_rate^2 \times (1 + \|d_t - d_o\|).$$

The error rate is squared and multiplied by $(1 + \|d_t - d_o\|)$ because the system typically believes that the decrease in the error rate outweighs the decrease in $\|d_t - d_o\|$. The smaller the fitness value is, the fitter the chromosome is.

Neural Network Evolution

The neural network classifier utilized in embodiments of the invention to classify plaque-like entities may comprise 20 input neurons, two hidden layers, each of which consists of 16 hidden units, and 5 output neurons. Thus, the system uses a feed-forward network with three layers of adaptive weights (the number of layers and adaptive weights may vary). The bias parameter is added to the input layer. Since networks having three layers of weights can generate arbitrary decision regions, which may be non-convex and disjoint, the resulting network can recognize any type of entity.

The neural network utilized by one embodiment of the invention accepts twenty relative descriptor amplitudes, $|z'_n|$ and $|z'_{-n}|$ for $n = 1,2,\ldots,10$, where

$$\left|z'_n\right| = \frac{|z_n|}{M},$$

where $M = \max\{|z_k| \mid k = \pm 1, \pm 2, \ldots, \pm 10\}$. Each output neuron corresponds to a specific class of entities. The outputs of all output neurons are compared. Then, the index of the output neuron which gives the largest value is returned as the class of the input plaque entity.

The genetic algorithm utilized in one embodiment of the invention is applied to connection weights. Since there are 672 weights, each of which is represented in a 32 bit

long vector, a chromosome in our genetic algorithm is 21,504 bits long. There are 400 chromosomes vying for survival. In one specific test, images comprising 43 single plaques, 48 double plaques, 39 triple plaques and 23 quadruple plaques were obtained. The expert user thresholded those images, calculated Fourier descriptors of each entity in the image and classified them to form a base data set for fitness evaluation in the genetic algorithm. Although the neural network can classify up to 5 classes, the expert user may provide samples for only 4 classes because the system could hardly find any plaque entities that are made up of 5 or more simple plaques. A test data set is set up at each fitness evaluation phase by randomly sampling 100 entities from the base set with replacement.

At every generation, chromosomes mutate and crossover. Next, they are evaluated by actually setting up all connections of the network from each chromosome and testing the network on a randomly chosen test data set. Then, chromosomes are sorted by their fitness values and selected. The surviving chromosomes reproduce themselves. The evolution lasts for 400 generations. After the evolution ends, the best chromosome is picked.

The neural network which has evolved in this manner can discriminate single plaques from other classes of plaque entities within the base test data set with 95% accuracy. The classifier also can classify plaque entities into three classes, i.e., single, double and other plaques, with 80% accuracy within the base test data set.

The Role of an Entity Classifier within a More General Histological Image Processing System

The neural network entity classifier has been integrated into a more general image processing system (e.g., a system for histological image processing). The host system loads the neural network classifier when it is started.

After candidate entities have been isolated, an entity classifier will come into use. Given the image of an entity, the classifier first traverses the boundary of the entity counterclockwise. Next, it calculates Fourier descriptors of the boundary using a discrete Fourier transform algorithm. Then, it feeds the relative descriptor amplitudes to the neural network and displays which class the entity belongs to. If users disagree with the classifier, they indicate which class they think the entity should belong to. Then, the input from users is sent to the neural network as a target input, and the network will adjust the connection weights just a little through a single application of error back propagation.

Fourier descriptors capture only the shape information of entities. Other information, such as size, color, texture, color gradient, and so on, will have become available by the time the entities are defined. Therefore, before applying the neural network classifier, the host system excludes some entities based on criteria other than shape. For example, tiny entities are likely to be screened out. Similarly, entities

of a faint color, even if they are not tiny, might also be rejected ahead of time.

As mentioned earlier, the majority of plaque entities to be classified are single plaques. Therefore, it is not very important for the classifier to discriminate one type of multiple plaque from another type of multiple plaque. The neural network classifier can distinguish single plaques from other classes of plaques, or vice versa, with 95% success. This level of accuracy is acceptable for our purposes.

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System Extensions

The system may be modified to utilize Bayesian inference with Fourier descriptors to yield improved performance. The system may also utilize other genetic algorithms to produce neural networks. The system may also combine Fourier descriptors and some other entity measures to classify entities. Fourier descriptors give information only on the outline of a histological entity. However, the entities are not merely closed outline curves. For example, some entities have a nearly round outline, but also have a two or more dark colored cores.

Information on entity size or texture can be provided to the classifier. There is a correlation between entity size and an entity class. Thus, this information could be helpful in performing analysis of image data. For instance, multiple plaques are usually larger than single plaques. This correlation should be useful for plaque entity classification; thus, the system may therefore comprise an entity classifier which will

accept size information as well as Fourier descriptors of an entity. Other types of information may also be provided. Prior probabilities might be used in conjunction with network outputs to estimate posterior probabilities.

Embodiment of Computer Execution Environment (Hardware)

An embodiment of the invention can be implemented as computer software in the form of computer readable program code executed on one or more general-purpose computers such as the computer 1000 illustrated in Figure 10. A keyboard 1010 and mouse 1011 are coupled to a bi-directional system bus 1018 (e.g., PCI, ISA or other similar architecture). The keyboard and mouse are for introducing user input to the computer system and communicating that user input to central processing unit (CPU) 1013. For instance, the keyboard and mouse, or any other input device may be utilized to collected information from the user about an image. Other suitable input devices may be used in addition to, or in place of, the mouse 1011 and keyboard 1010. I/O (input/output) unit 1019 coupled to bi-directional system bus 1018 represents possible output devices such as a printer or an A/V (audio/video) device.

Computer 1000 includes video memory 1014, main memory 1015, mass storage 1012, and communication interface 1020. All these devices are coupled to a bi-directional system bus 1018 along with keyboard 1010, mouse 1011 and CPU 1013. The mass storage 1012 may include both fixed and removable media, such as magnetic, optical or magnetic optical storage systems or any other available mass storage

technology. The system bus 1018 provides a means for addressing video memory 1014 or main memory 1015. The system bus 1018 also provides a mechanism for the CPU to transferring data between and among the components, such as main memory 1015, video memory 1014 and mass storage 1012.

In one embodiment of the invention, the CPU 1013 is a microprocessor manufactured by Motorola, such as the 6080X0 processor, an Intel Pentium III processor, or an UltraSparc processor from Sun Microsystems. However, any other suitable processor or computer may be utilized. Video memory 1014 is a dual ported video random access memory. One port of the video memory 1014 is coupled to video accelerator 1016. The video accelerator device 1016 is used to drive a CRT (cathode ray tube), and LCD (Liquid Crystal Display), or TFT (Thin-Film Transistor) monitor 1017. The video accelerator 1016 is well known in the art and may be implemented by any suitable apparatus. This circuitry converts pixel data stored in video memory 1014 to a signal suitable for use by monitor 1017. The monitor 1017 is a type of monitor suitable for displaying graphic images such as the images to be quantified.

The computer 1000 may also include a communication interface 1020 coupled to the system bus 1018. The communication interface 1020 provides a two-way data communication coupling via a network link 1021 to a network 1022. For example, if the communication interface 1020 is a modem, the communication interface 1020 provides a data communication connection to a corresponding type of telephone line, which comprises part of a network link 1021. If the communication interface 1020 is a Network

Interface Card (NIC), communication interface 1020 provides a data communication connection via a network link 1021 to a compatible network. Physical network links can include Ethernet, wireless, fiber optic, and cable television type links. In any such implementation, communication interface 1020 sends and receives electrical, electromagnetic or optical signals which carry digital data streams representing various types of information.

The network link 1021 typically provides data communication through one or more networks to other data devices. For example, network link 1021 may provide a connection through local network 1022 to a host computer 1023 or to data equipment operated by an Internet Service Provider (ISP) 1024. ISP 1024 in turn provides data communication services through the world wide packet data communication network now commonly referred to as the "Internet" 1025. Local network 1022 and Internet 1025 both use electrical, electromagnetic or optical signals that carry digital data streams to files. The signals through the various networks and the signals on network link 1021 and through communication interface 1020, which carry the digital data to and from computer 1000, are exemplary forms of carrier waves for transporting the digital information.

The computer 1000 can send messages and receive data, including program code, through the network(s), network link 1021, and communication interface 1020. In the Internet example, server 1026 might transmit a requested code for an application program through Internet 1025, ISP 1024, local network 1022 and communication interface 1020. The user may therefore operate an interface to the image processing system from a

remote location. Aspects of the invention may be embodied in server 1026 or a client computer connected to the network. Processing may occur on server 1026, computer 1000, or any other computer and the result can be delivered to the user via the network. The invention therefore contemplates the use of web-based system and/or client-server based systems embodying the invention. Alternatively, a single computer may function as a stand-alone device adapted to execute the image processing system described herein.

The computer systems described above are for purposes of example only. An embodiment of the invention may be implemented in any type of computer system or programming or processing environment. When a general-purpose computer system such as the one described executes the process and process flows described herein, it is configured to provide a mechanism for automating the expert quantification of image data.

Thus, a method and apparatus for generating special-purpose image analysis algorithms based on the expert quantification of image data is described. Particular embodiments described herein are illustrative only and should not limit the present invention thereby. The claims and their full scope of equivalents define the invention.

DRAFT - ATTORNEY WORK PRODUCT

CLAIMS

What is claimed is:

1. A computer program product for generating special-purpose image analysis algorithms comprising:

a computer usable medium having computer readable program code embodied therein, said computer readable program code configured to:

obtain at least one image having a plurality of chromatic data points;

generate an evolving algorithm that partitions said plurality of chromatic data points within said at least one image into at least one entity identified in accordance with a user's judgment; and

store a first instance of said evolving algorithm as a product algorithm wherein said product algorithm enables the automatic classification of instances of said at least one entity within at least one second image in accordance with said judgment of said user.

2. The computer program product of claim 1 wherein said computer readable medium is further configured to evolve a second instance of said evolving algorithm in accordance with further input from said user.

3. The computer program product of claim 1 wherein said computer readable medium is further configured to iteratively recruit said judgment from said user

for input to said evolving algorithm via a user interface configured to accept said judgment as input parameters to said evolving algorithm.

4. The computer program product of claim 1 wherein said computer readable program code configured to generate said evolving algorithm further comprises computer readable program code configured to:

obtain a sample set of said plurality of chromatic data points;

execute a first iteration of said evolving algorithm using said sample set;

present a first set of identified entities within said image to said user for feedback as to the accuracy of said first set of identified entities;

obtain said feedback from said user;

execute a second iteration of said evolving algorithm using said feedback as a supplement to said sample set of said plurality of chromatic data points; and

present a second set of identified entities within said image to said user for additional feedback as to the accuracy of said second set of identified entities.

5. The computer program product of claim 4 wherein said user selects said sample set of said plurality of chromatic data points via an input device.

6. The computer program product of claim 4 wherein said evolving algorithm utilizes a Bayesian classifier during execution of said second iteration of said

evolving algorithm.

7. The computer program product of claim 1 further comprising:

evaluating said at least one image to determine a first probability measure associated with at least one pixel class;

assigning said plurality of chromatic data points to said at least one pixel class in accordance with said first probability measure.

8. The computer program product of claim 7 further wherein said computer readable program code obtains a pixel zoo comprising representative samples of pixel-measure vectors from said at least one pixel class and utilizes said pixel zoo as input to said evolving algorithm.

9. The computer program product of claim 7 wherein said first probability measure comprises a prior probability that a randomly selected chromatic data point of said plurality of chromatic data points belongs to said at least one pixel class and a conditional probability density function characterizing a distribution of pixel-measure vectors within said plurality of chromatic data points assigned to said at least one pixel class.

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10. The computer program product of claim 9 wherein said pixel-measure vectors comprise context-sensitive data reflecting aspects of light spectral values assigned to other pixels in said at least one pixel class.

11. The computer program product of claim 9 wherein said pixel-measure vectors comprise context-independent data reflecting aspects of light spectral values assigned to other pixels in said at least one pixel class.

12. The computer program product of claim 1 wherein said computer readable program code configured to generate said evolving algorithm further comprises computer readable program code configured to:

apply at least one vector-valued function to at least one user-specified subset of chromatic data points wherein said at least one vector-valued function measures a set of properties of said user-specified subset.

13. The computer program product of claim 12 further comprising computer readable program code configured to:

accept at least one user-specified subset of said plurality of chromatic data points that belongs to a given at least one entity class;

construct from said user-specified at least one subset belonging to said at least one entity class a second probability measure associated with said at least one entity class, where said second probability measure further comprises a prior

probability and a conditional probability density function on said at least one vector-valued function reflecting, for any entity measure vector value v, the probability that a subset of said plurality of chromatic data points belonging to said entity class yields an entity measure vector with said entity measure vector value v;

partition said plurality of chromatic data points into at least one subset in accordance with the judgment of said user;

evaluate said at least one image utilizing said second probability measure so as to partition said plurality of chromatic data points into subsets belonging to said at least one entity class.

14. The computer program product of claim 13 wherein said user-specified subset comprises a maximal, spatially connected subset of said plurality of chromatic data points such that each of said plurality of chromatic data points in said spatially connected subset belong to a pixel class.

15. The computer program product of claim 13 wherein said user-specified subset of said plurality of chromatic data points satisfies the following conditions: (a) said plurality of chromatic data points in said user-specified subset are in a same pixel class, (b) each of said plurality of chromatic data points in said subset is within a first distance from at least one other chromatic data point in S, and (c) there exist

no other chromatic data points in the image satisfying both of said conditions (a) and (b).

16. The computer program product of claim 13 wherein said second probability measure is adjusted in accordance with said judgment of said user.

17. The computer program product of claim 1 wherein the judgment of said user comprises a verification obtained via a verification message.

18. The computer program product of claim 17 wherein said verification message is transmitted to said user via an interconnection fabric.

19. The computer program of claim 1 wherein said evolving algorithm determines a classification of said at least one entities in said at least one image.

20. The computer program of claim 1 wherein said evolving algorithm utilizes non-visual data.

21. The method of claim 20 wherein said non-visual information comprises stage of disease factors.

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22. The method of claim 20 wherein said non-visual information comprises demographic information.

23. The method of claim 20 wherein said non-visual information comprises genetic information.

24. The method of claim 20 wherein stage of disease factors contribute to probability estimations.

25. A computer program product for generating special-purpose image analysis algorithms comprising:

a computer usable medium having computer readable program code embodied therein, said computer readable program code configured to:

obtain at least one image from an image source wherein said at least one image comprises a plurality of chromatic data points;

obtain a sample set of said plurality of chromatic data points;

execute a first iteration of an evolving algorithm comprising a first partition operation that partitions said sample set into a first set of identified entities;

present said first set of identified entities within said image to said user for feedback as to the accuracy of said first partition operation;

obtain said feedback from said user; execute a second iteration of said evolving algorithm using said feedback to supplement said sample set of said plurality of chromatic data points, wherein said second iteration of said evolving algorithm comprises second partition operation that partitions said plurality of chromatic data points into a second set of identified entities;

present said second set of identified entities within said image to said user for additional feedback as to the accuracy of said second partition operation;

obtain approval from said user to commit said evolving algorithm; and

upon said approval store a first instance of said evolving algorithm as a product algorithm wherein said product algorithm enables the automatic classification of instances of said at least one entity within at least one second image in accordance with said judgment of said user.

26. A computer program product for generating special-purpose image analysis algorithms comprising:

a computer usable medium having computer readable program code embodied therein, said computer readable program code configured to:

obtain at least one image from an image source wherein said at least one image comprises a plurality of chromatic data points;

obtain a sample set of said plurality of chromatic data points;

execute a first iteration of an evolving algorithm that partitions said sample set into at least one pixel class, wherein said evolving algorithm is capable

of evaluating said sample set to determine a first probability measure, wherein said first probability measure comprises a prior probability that a randomly selected chromatic data point in said plurality of chromatic data points belongs to said at least one pixel class and a conditional probability density function characterizing a distribution of pixel-measure vectors associated with said plurality of chromatic data points assigned to said at least one pixel class, wherein said evolving algorithm assigns each chromatic data point in said plurality of chromatic data points to one of the said at least one pixel classes in accordance with said first probability measure and is configured to use said first probability measure to produce a first pixel classification image, in which each chromatic data point within said at least one image is assigned to said at least one pixel class;

present said first pixel classification image to said user for feedback as to the accuracy ;

obtain said feedback from said user;

revise said first probability measure to accommodate said feedback from said user;

execute a second iteration of said evolving algorithm using said revised first probability measure;

present a second pixel classification image to said user for additional feedback as to accuracy;

obtain approval from said user to commit said evolving algorithm; and

upon said approval store a first instance of said evolving algorithm as a product algorithm wherein said product algorithm enables the automatic classification of instances of said at least one chromatic data point within at least one second image in accordance with said judgment of said user.

27. A computer program product for generating special-purpose image analysis algorithms comprising:

a computer usable medium having computer readable program code embodied therein, said computer readable program code configured to:

obtain at least one image from an image source wherein said at least one image comprises a plurality of chromatic data points;

obtain a sample set of said plurality of chromatic data points;

execute a first iteration of an evolving algorithm that partitions said sample set into at least one pixel class, wherein said first iteration of said evolving algorithm is capable of evaluating said sample set to determine a first probability measure comprising a prior probability that a randomly selected chromatic data point in said plurality of chromatic data points belongs to said at least one pixel class and a conditional probability density function characterizing a distribution of pixel-measure vectors associated with said at least one pixel class;

assign each chromatic data point in said plurality of chromatic data points to one of said at least one pixel classes in accordance with said first probability measure, wherein said evolving algorithm is configured to use said first

probability measure to produce a first pixel classification image, in which each chromatic data point within said at least one image is assigned to exactly one of said at least one pixel classes;

present said first pixel classification image to said user for feedback as to the accuracy;

obtain said feedback from said user;

revise said first probability measure to accommodate said feedback from said user;

execute a second iteration of said evolving algorithm using said revised first probability measure;

present a second pixel classification image to said user for additional feedback as to accuracy;

obtain approval from said user to commit said evolving algorithm;

obtain at least one user-specified subset of pixels, wherein each said subset is exemplary of an entity type within said at least one image;

apply at least one vector-valued function to said at least one user-specified subset wherein said at least one vector-valued function measures a set of properties of said user-specified subset;

use said at least one vector-valued function to estimate a second probability measure, wherein said evolving algorithm is configured to use said second probability measure to identify a first set of entities within said at least one image;

present said first set of entities within said image to said user for feedback as to the accuracy of said identification of said first set of entities;

obtain said feedback from said user;

revise said second probability measure to accommodate said feedback from said user;

execute a third iteration of said evolving algorithm using said feedback, wherein said third iteration of said evolving algorithm uses said feedback to modify said second probability measure and utilize said modified second probability measure to identify a second set of identified entities within said at least one image;

present said second set of identified entities within said image to said user for additional feedback as to the accuracy of said identification of said second set of identified entities;

obtain approval from said user to commit said evolving algorithm;

upon said approval store a first instance of said evolving algorithm as a product algorithm wherein said product algorithm enables the automatic classification of instances of said at least one second set of identified entities within at least one second image in accordance with said judgment of said user.

28. In a computer system, a method for automating the expert quantification of image data using a product algorithm comprising:

obtaining a product algorithm for analysis of a first set of image data wherein said product algorithm is configured to recognize at least one entity within said first set of image data via a training mode that utilizes input to an evolving algorithm obtained from at least one first user, and;

providing said product algorithm to at least one second user so that said at least one second user can apply said product algorithm against a second set of image data having said at least one entity.

29. In a computer system, a method for automating the expert quantification of image data using a product algorithm comprising:

obtaining a product algorithm for analysis of a first set of image data wherein said product algorithm is configured to recognize at least one entity within said first set of image data via a training mode that utilizes iterative input to an evolving algorithm obtained from at least one first user, wherein said training mode comprises:

presenting a first set of said at least one entity to said user for feedback as to the accuracy of said first set of identified entities;

obtaining said feedback from said user;

executing said evolving algorithm using said feedback;

presenting a second set of said at least one entity to said user for feedback as to the accuracy of said second set of identified entities;

obtaining approval from said user about said second set of entities;

storing said evolving algorithm as a product algorithm;

providing said product algorithm to at least one second user so that said at least one second user can apply said product algorithm against a second set of image data having said at least one entity.

30. The method of claim 29 wherein said evolving algorithm comprises a neural network.

31. The method of claim 29 wherein said evolving algorithm comprises a classification engine.

32. The method of claim 29 wherein said product algorithm comprises a pixel zoo.

33. The method of claim 29 wherein said product algorithm comprises a pixel zoo.

34. The method of claim 29 wherein said product algorithm comprises an entity zoo.

35. A computer program product comprising:

a memory medium embodying computer readable program code for automating the expert quantification of image data, said computer readable program code configured to:

obtain image data having a plurality of chromatic data points;

identify which of said plurality of chromatic data points comprise an entity;

group said plurality of chromatic data points into a plurality of spatially connected subsets;

determine a plurality of characteristics about said spatially connected subsets;

pass said plurality of characteristics to a classification engine.

classify said plurality of spatially connected subsets into at least one classification;

obtaining affirmation of the veracity of said at least one classification from a user;

evaluate said spatially connected subset to derive a set of relative harmonic amplitudes;

pass said relative harmonics into a neural network, wherein said neural network is trained to classify said spatially connected subsets using shape information provided by said set of relative harmonic amplitudes;

present a result of said classification to said user;

obtain verification of said classification from said user;

using said verification to adjust said neural network.

EXHIBIT G

36. In a computer system, a method for automating the expert quantification of image data comprising:

collecting image data;

thresholding said image data based on features of said image data;

classifying entities in said image data via a classification engine;

determining the edge of said entities via a neural network engine;

presenting a classification to a user for verification;

storing input to said classification engine upon said verification for later use.

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Docket Alarm, Inc.

ABSTRACT OF THE DISCLOSURE

One embodiment of the invention provides a process and related apparatus for obtaining quantitative data about a 2-dimensional, 3-dimensional image, or other dimensional image. For example, the invention is capable of classifying and counting the number of entities an image contains. Each entity comprises an entity, structure, or some other type of identifiable portion of the image having definable characteristics. The entities located within an image may have a different shape, color, texture, or other definable characteristic, but still belong to the same classification. In other instances, entities comprising a similar color, and texture may be classified as one type while entities comprising a different color, and texture may be classified as another type. An image may contain multiple entities and each entity may belong to a different class. Thus, the system embodying the invention may quantify image data according to a set of changing criteria and derive one or more classifications for the entities in the image. Once the image data is classified, the total number of entities in the image is calculated and presented to the user. Put simply, embodiments of the invention provides a way for a computer to determine what kind of entities (e.g., entities) are in an image and counts the total number of entities that can be visually identified in the image. Another aspect of the invention is that the information utilized during a training process may be stored and applied across different images.

EXHIBIT G

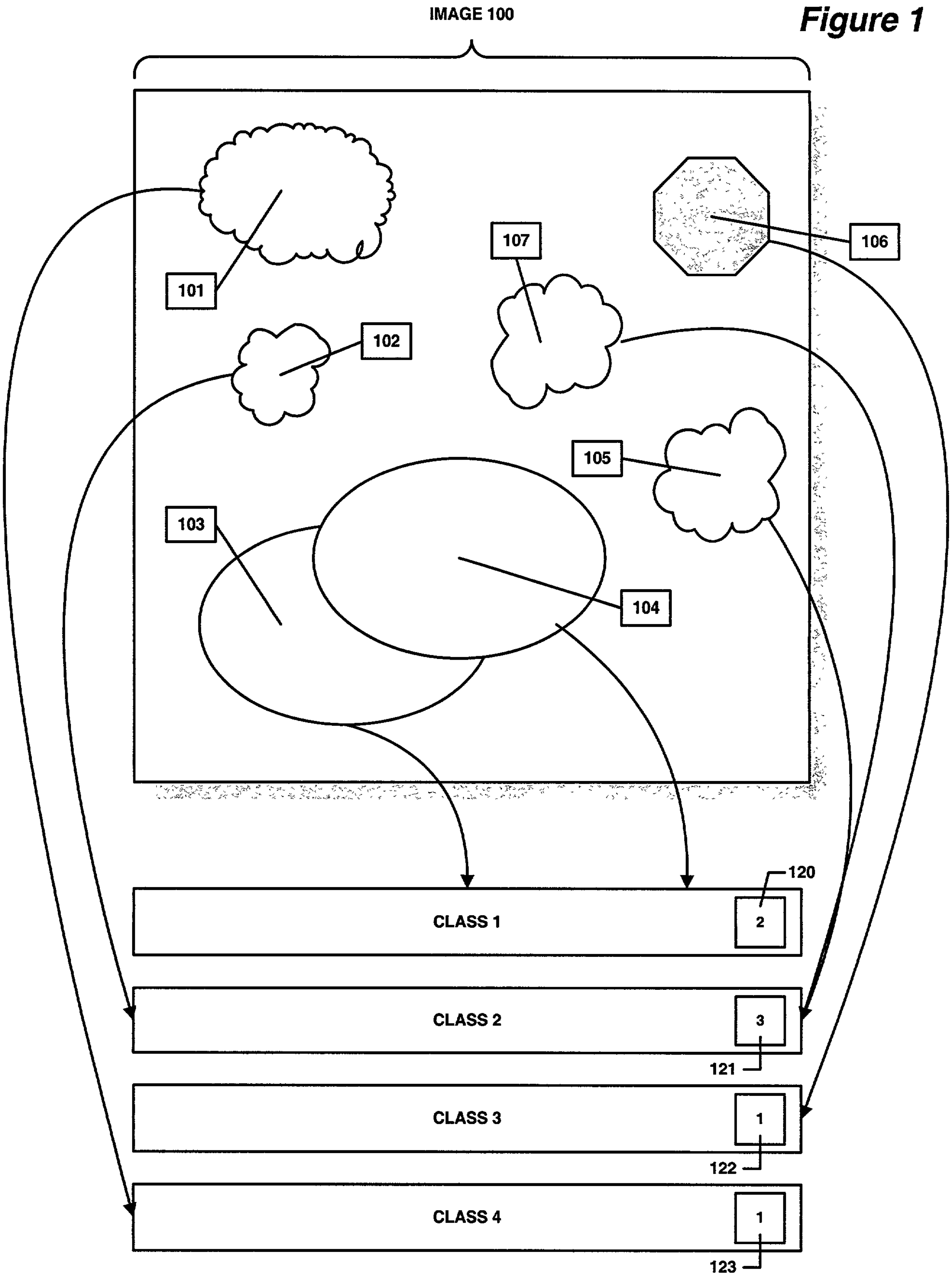

Figure 1

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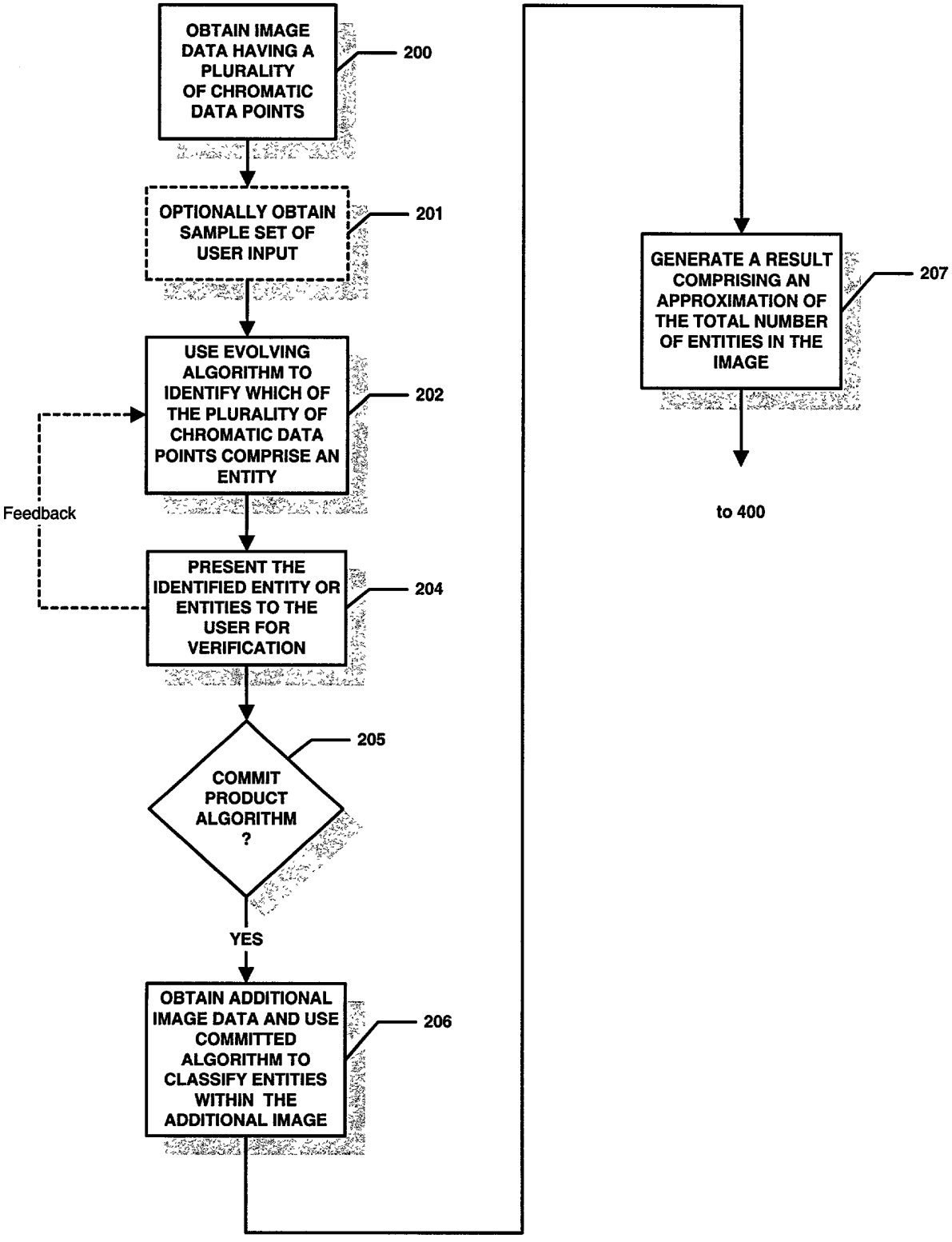
Figure 2



Patent No. 7,953,693

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Figure 3

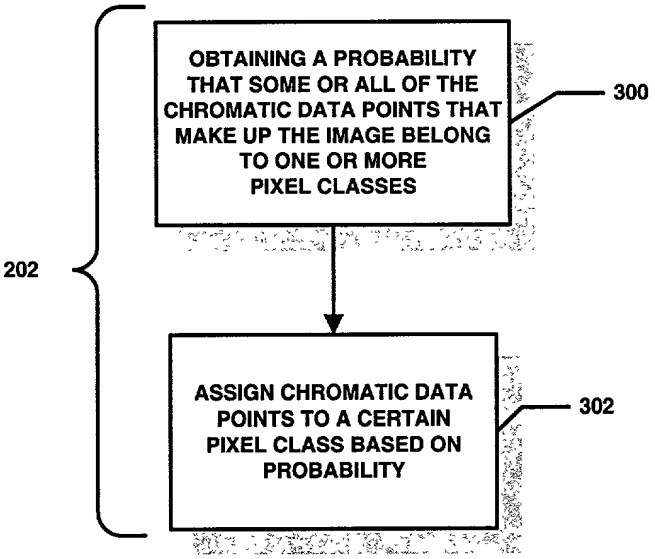

Figure 4

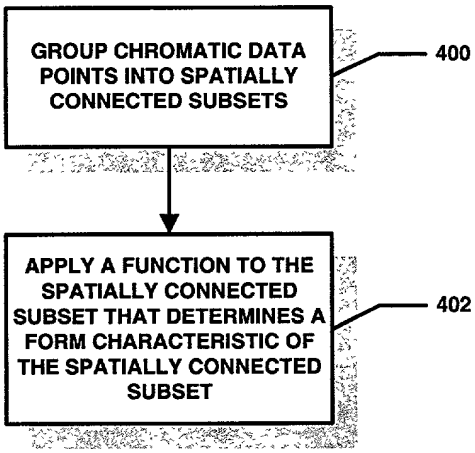

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Figure 5

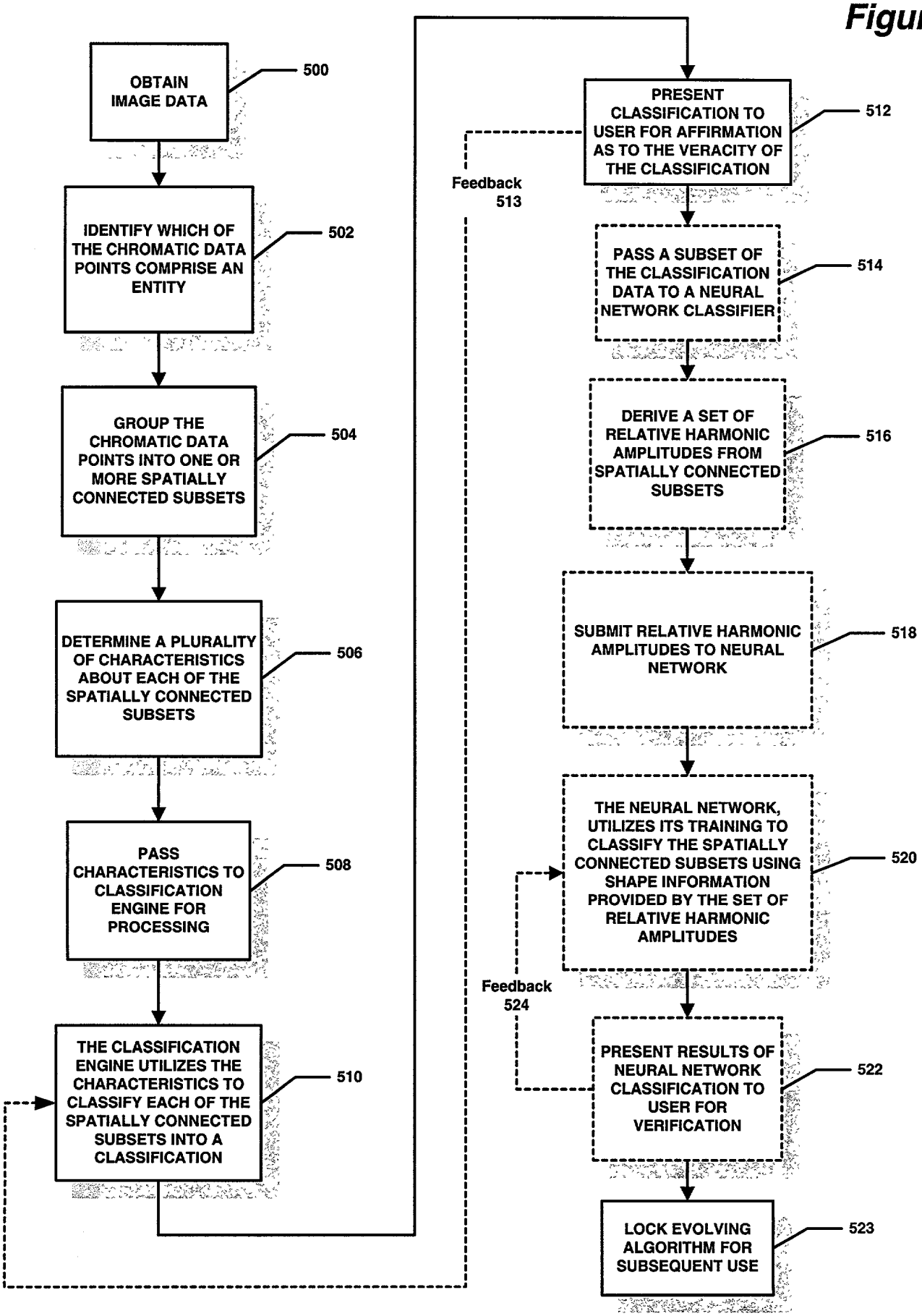

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Figure 6

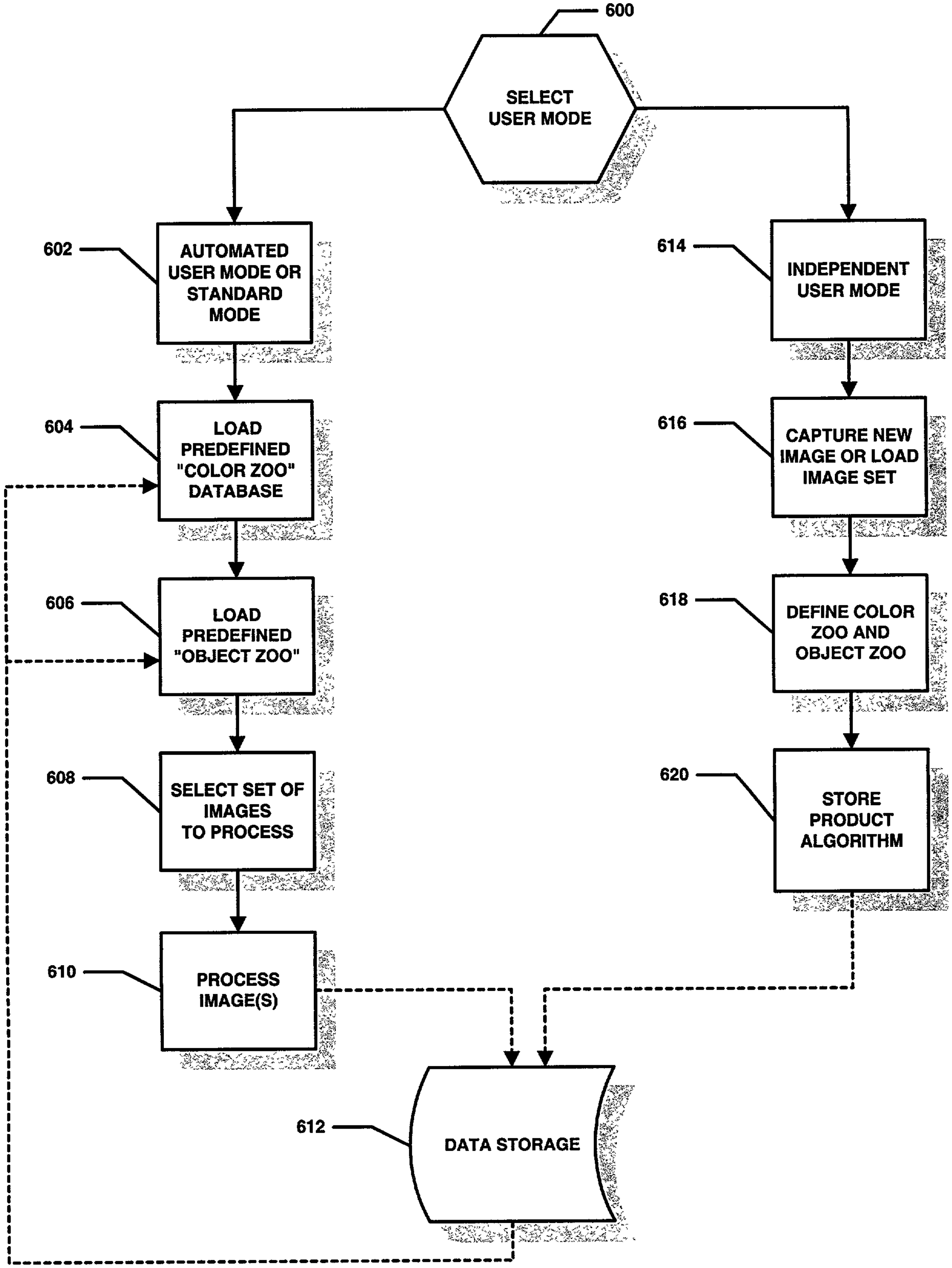

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Figure 7

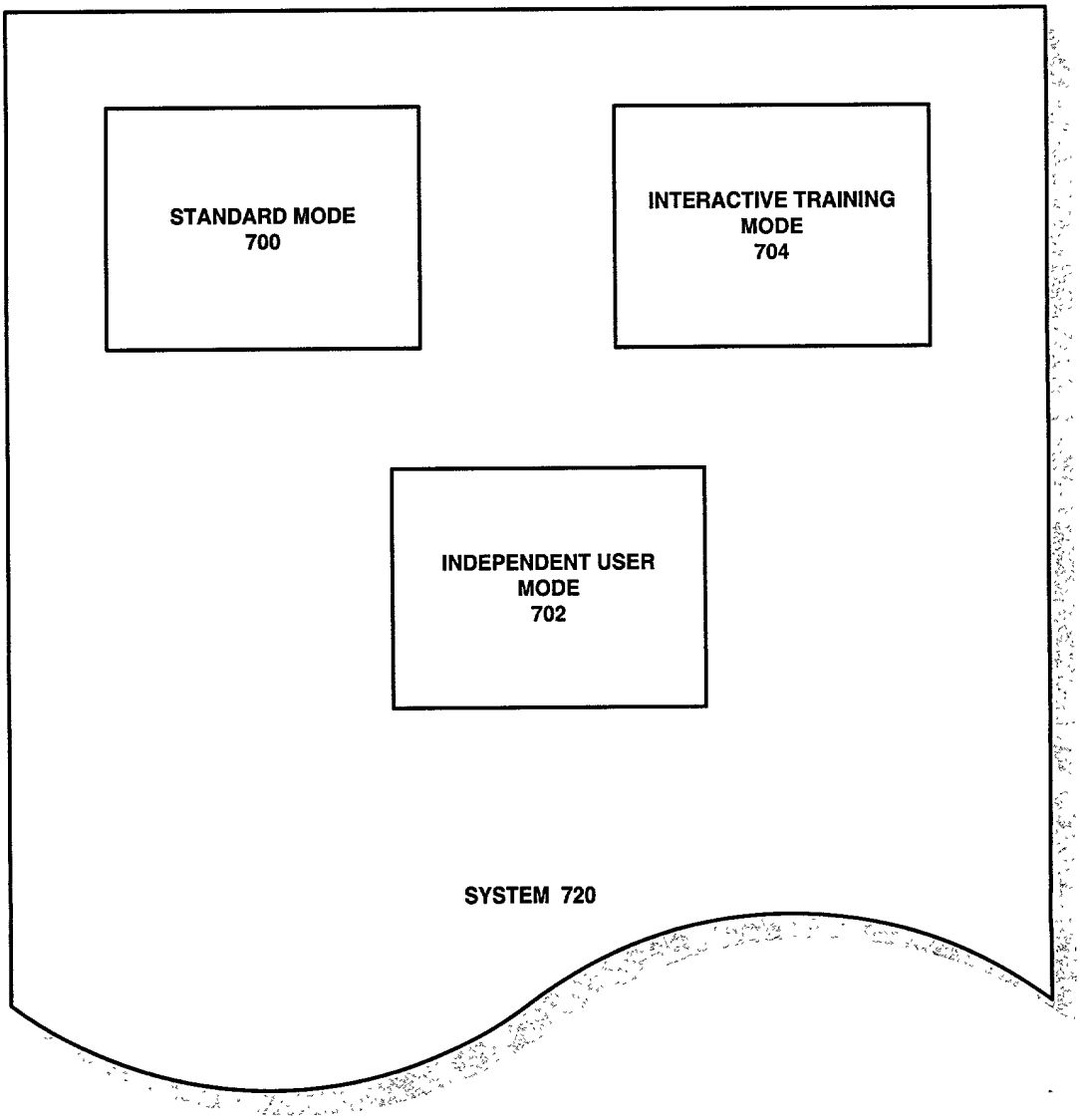

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Figure 8

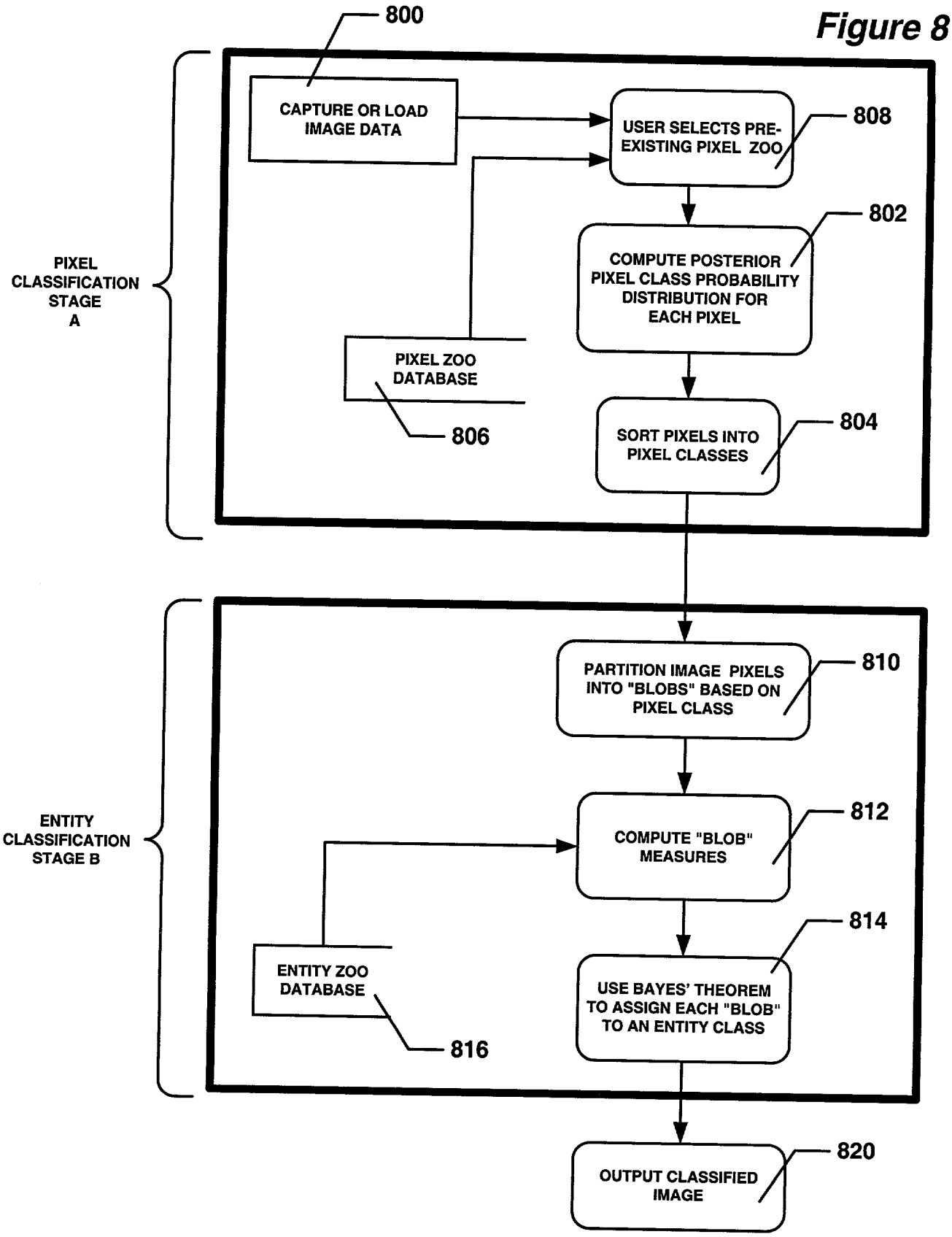

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Figure 9

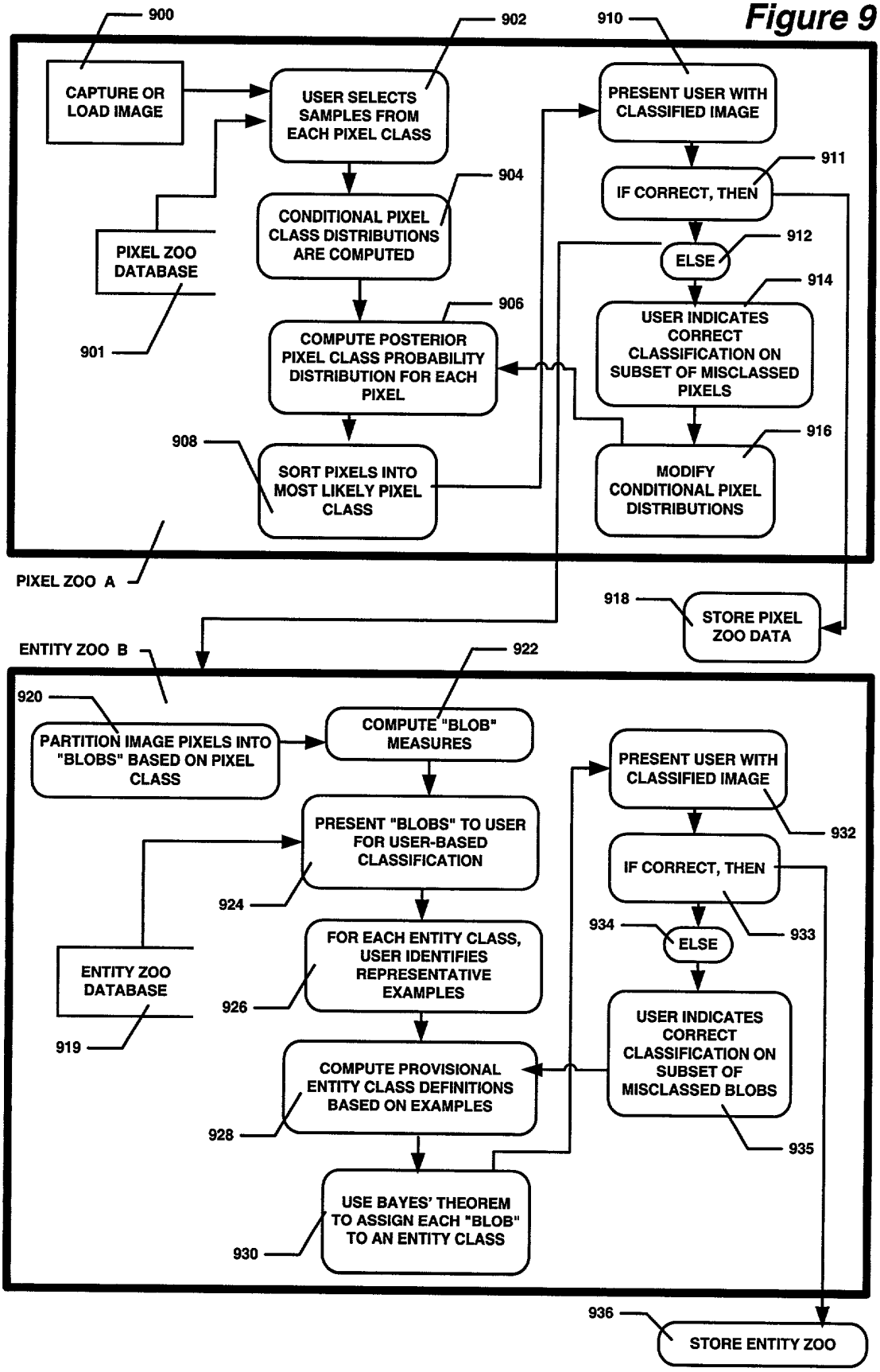


EXHIBIT 2009

Figure 10

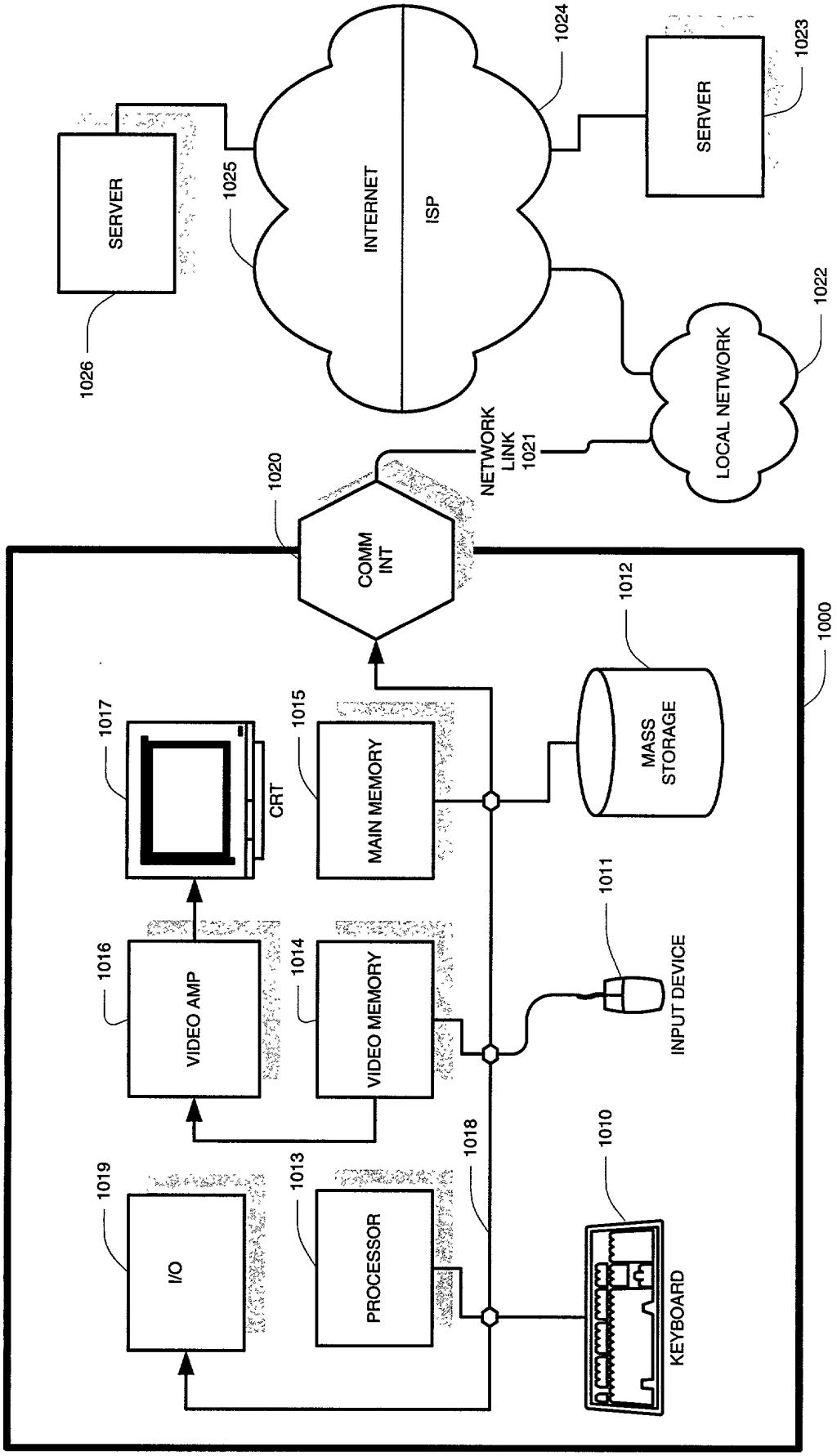
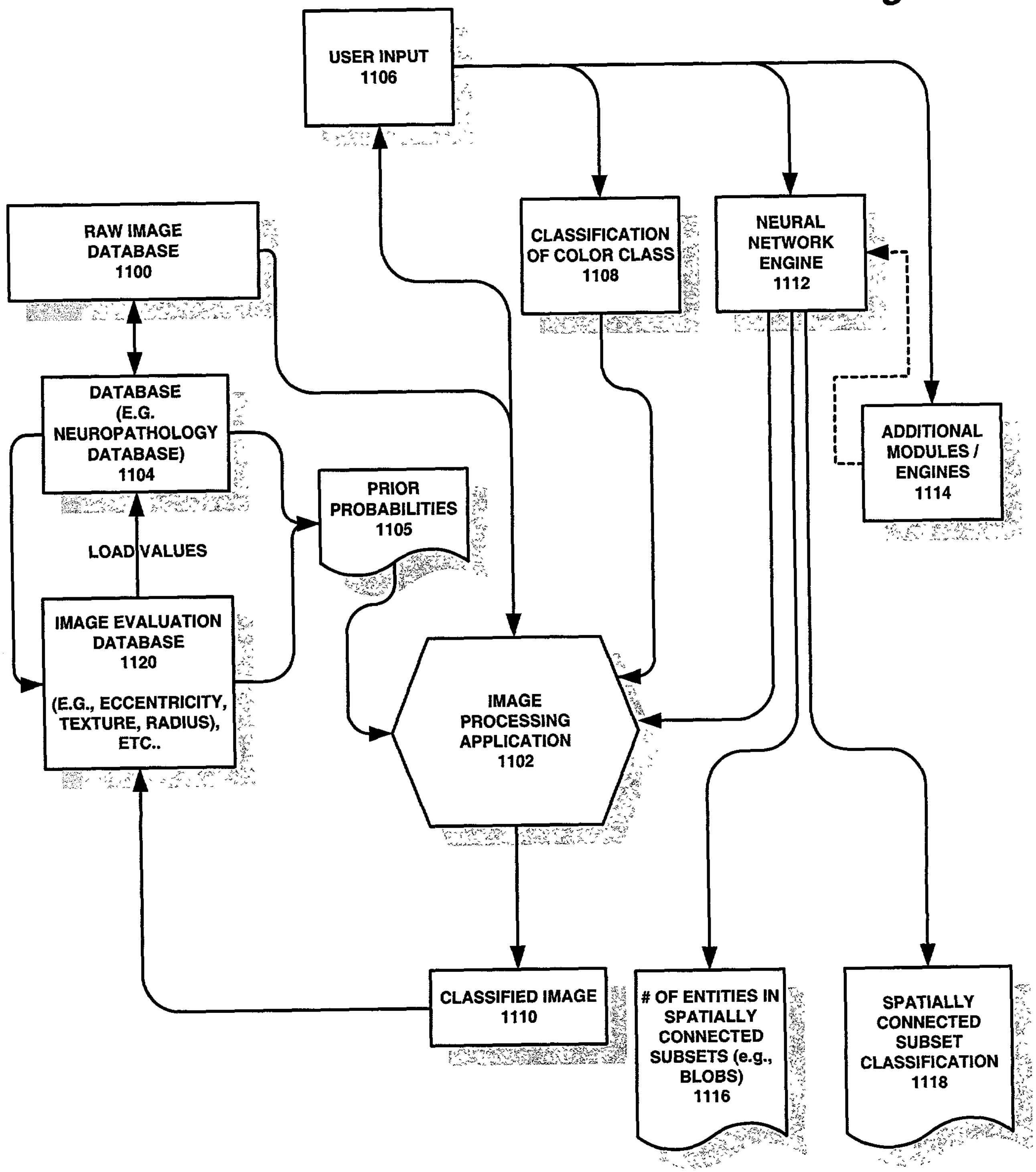

SERVER
1026
1025
INTERNET
ISP
1024
SERVER
1023
LOCAL NETWORK
1022
NETWORK LINK 1021
1020
COMM INT
1000
1012
MASS STORAGE
1017
CRT
1015
MAIN MEMORY
1016
VIDEO AMP
1014
VIDEO MEMORY
1011
INPUT DEVICE
1019
I/O
1013
PROCESSOR
1018
1010
KEYBOARD

EXHIBIT G

Figure 11



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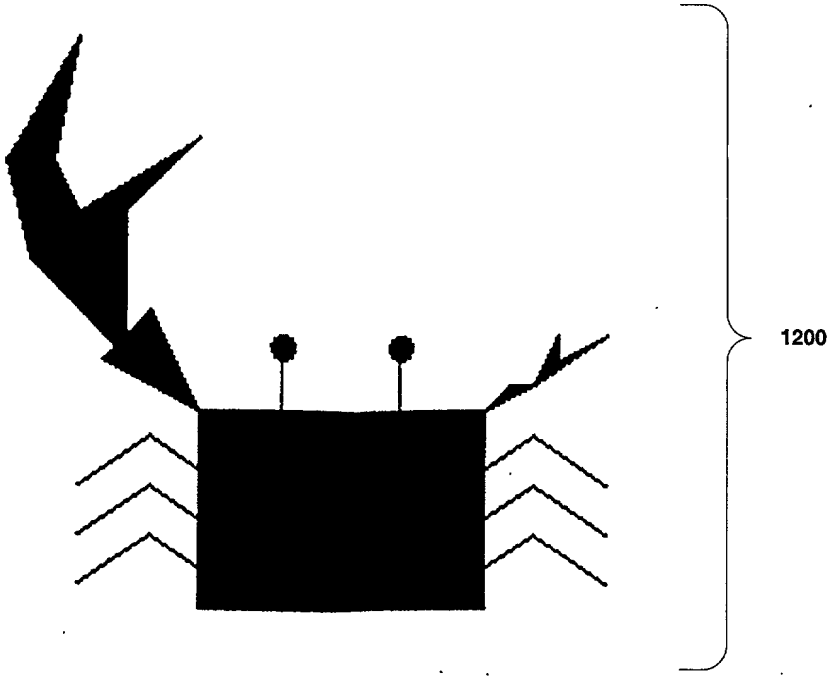

Figure 12 **Original image**

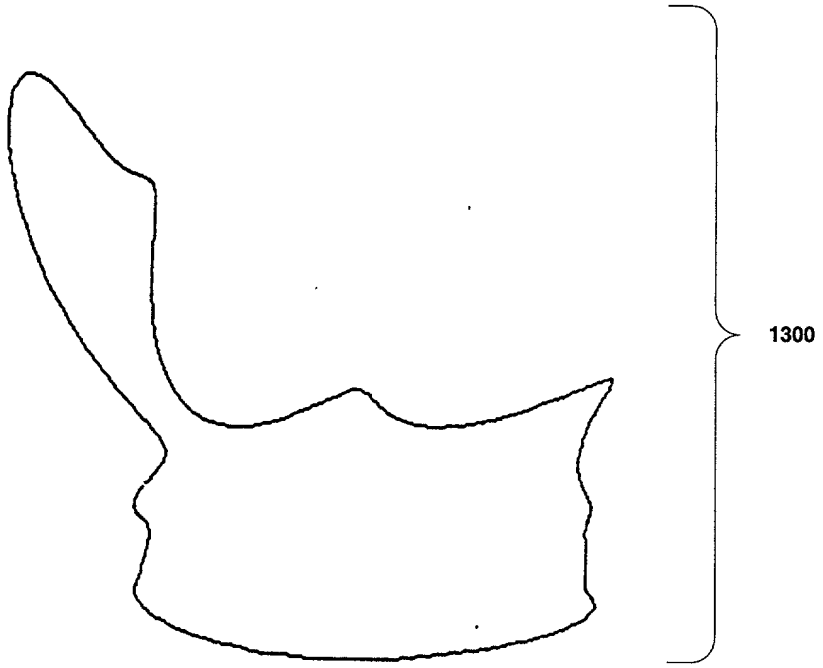

Figure 13 **Reconstructed outline (k = 10)**

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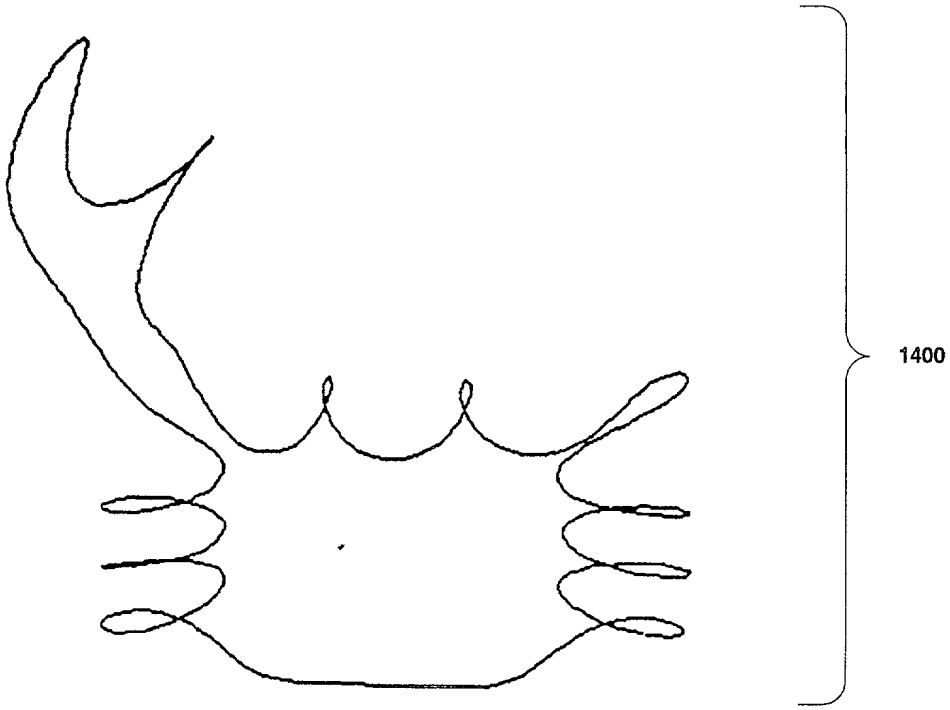

Figure 14 Reconstructed outline ($K = 20$)

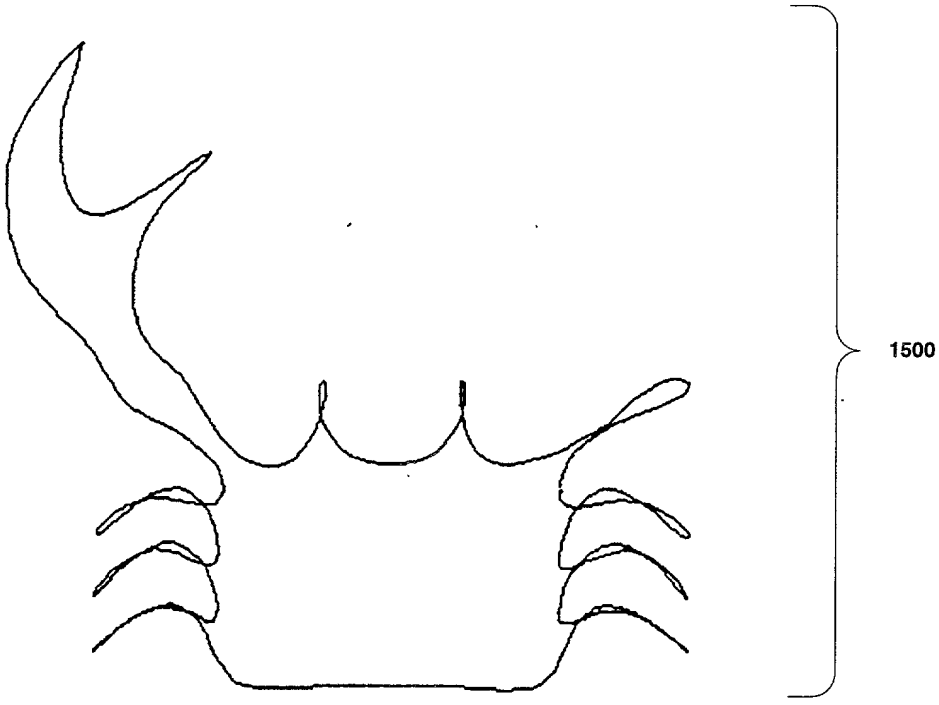

Figure 15 Reconstructed outline ($k = 30$)

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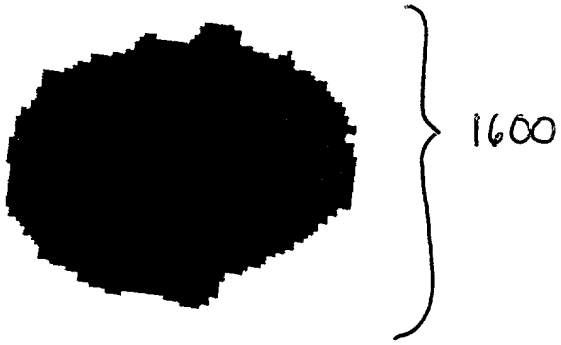

Figure 16 **Thresholded image of a single plaque sample**

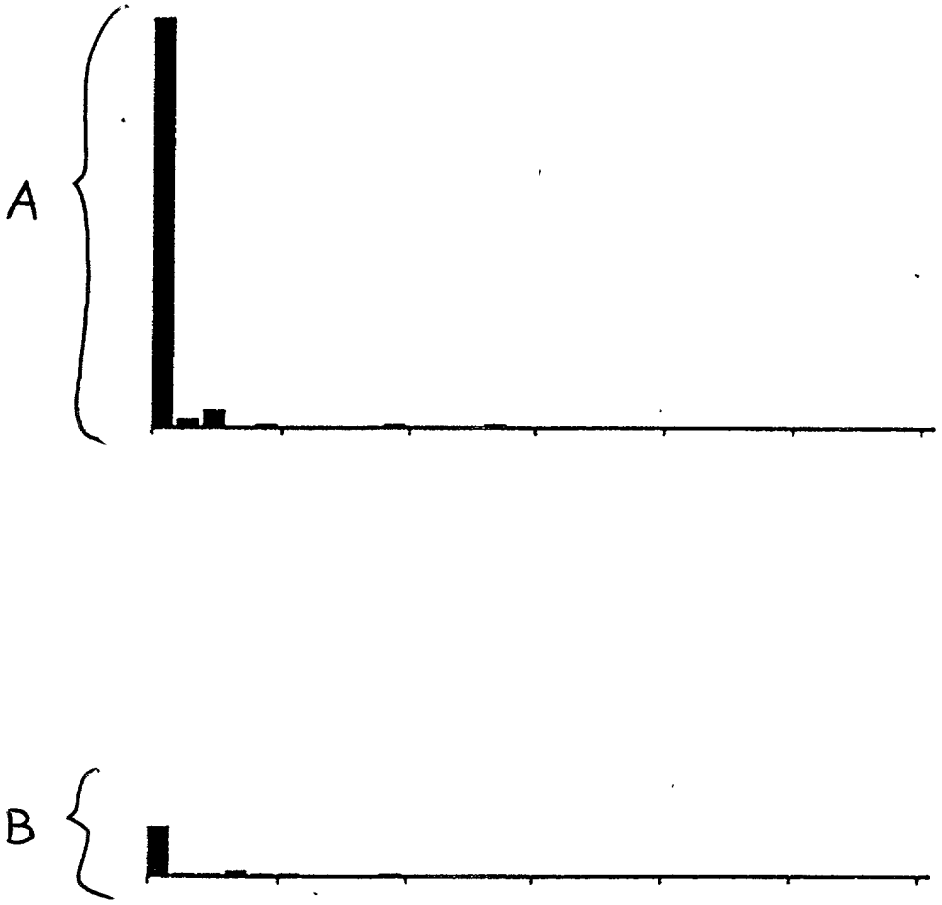

Figure 17 **Relative Fourier descriptors of** ***Figure 16***

Figure 18 **Thresholded image of a double plaque sample**

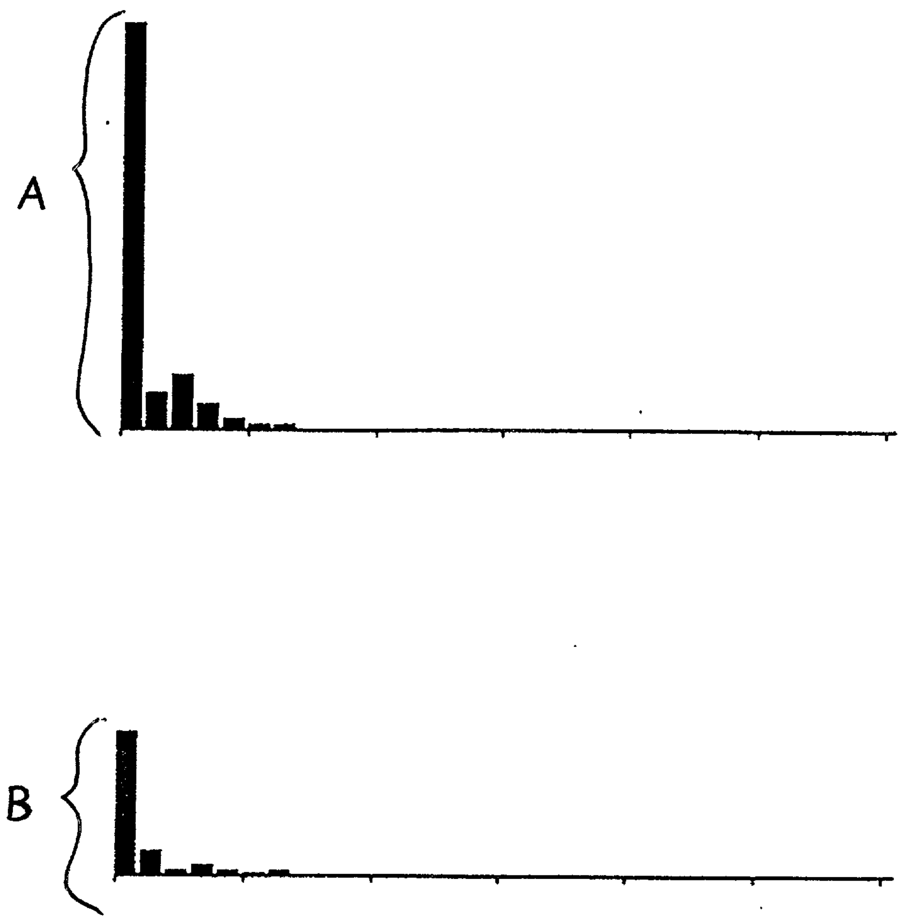

Figure 19 **Relative Fourier descriptors of** ***Figure 18***

EXHIBIT G

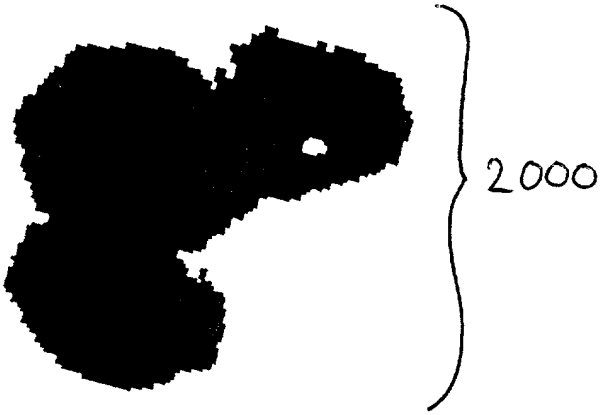

Figure 20 **Thresholded image of a triple plaque sample**

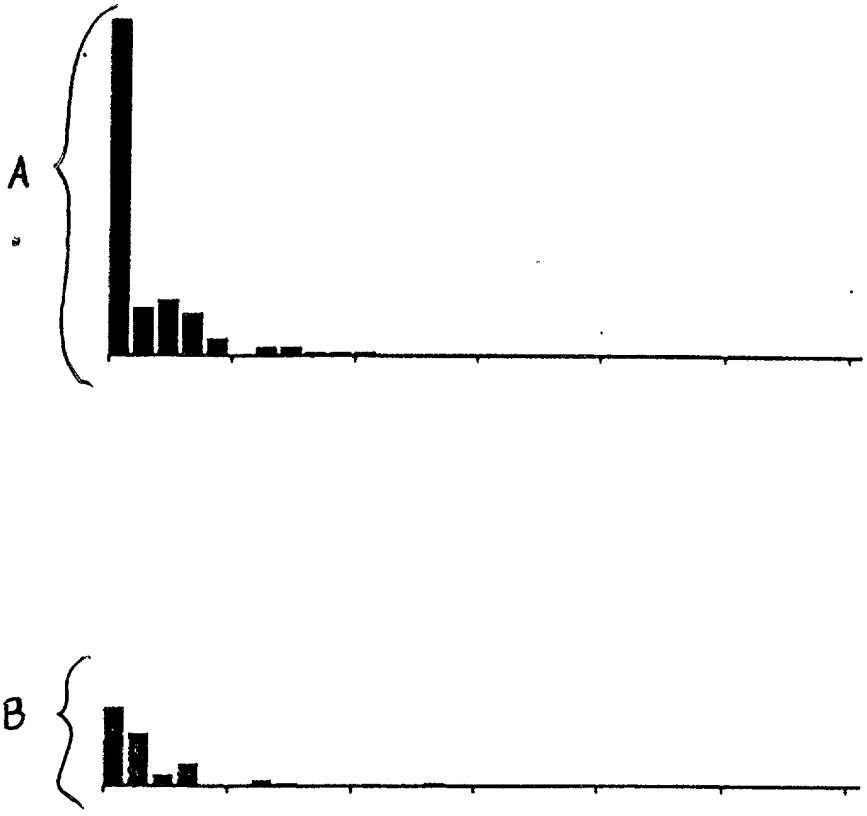

Figure 21 **. Relative Fourier descriptors of** ***Figure 20***

EXHIBIT G

Docket No.: 86200.911

DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

As below named inventors, We hereby declare that:

Our residence, post office addresses and citizenship is as stated below, next to our names,

We believe we are the original, first and joint inventors of the subject matter which is claimed and for which a patent is sought on the invention entitled

METHOD AND APPARATUS FOR GENERATING SPECIAL-PURPOSE IMAGE ANALYSIS ALGORITHMS

the specification of which is attached hereto.

We hereby state that we have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above. We do not know and do not believe that the same was ever known or used in the United States of America before our invention thereof, or patented or described in any printed publication in any country before our invention thereof or more than one year prior to this application, that the same was not in public use or on sale in the United States of America more than one year prior to this application, and that the invention has not been patented or made the subject of an inventor's certificate issued before the date of this application in any country foreign to the United States of America on an application filed by us or our legal representatives or assigns more than twelve months prior to this application.

We acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

We hereby appoint attorneys at PTO Customer Number 22804, as our attorneys with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith.

We hereby declare that all statements made herein of our own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under §1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

EXHIBIT G

Docket No.: 86200.911

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Inventor's Signature Carl W. Cotman Date 4/25/02

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Inventor's Signature Y. Inagaki Date 4/25/02

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EXHIBIT G

Docket No.: 86200.911

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Inventor's Signature [signature] Date 4/25/02

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CERTIFICATE OF MAILING
This is to certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as Express Mail Label No. EL938707773US *in an envelope addressed to: Assistant Commissioner for Patents Washington, D.C. 20231 on:* 4-25-02

[signature] 4-25-02
Signature *Date*

EXHIBIT G

PATENT APPLICATION SERIAL NO. _____

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE
FEE RECORD SHEET

05/01/2002 WABRHAM1 00000037 081520 10134157

01 FC:201 370.00 CH
02 FC:203 144.00 CH
03 FC:202 210.00 CH

PTO-1556
(5/87)

*U.S. Government Printing Office: 2001 — 481-697/59173

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PATENT APPLICATION FEE DETERMINATION RECORD
Effective October 1, 2001

Application or Docket Number: 10134157

CLAIMS AS FILED - PART I

	(Column 1)	(Column 2)
TOTAL CLAIMS	36	
FOR	NUMBER FILED	NUMBER EXTRA
TOTAL CHARGEABLE CLAIMS	36 minus 20=	* 16
INDEPENDENT CLAIMS	8 minus 3 =	* 5
MULTIPLE DEPENDENT CLAIM PRESENT		☐

* If the difference in column 1 is less than zero, enter "0" in column 2

SMALL ENTITY TYPE ☐ OR OTHER THAN SMALL ENTITY

RATE	FEE	OR	RATE	FEE
BASIC FEE	370.00	OR	BASIC FEE	740.00
X$ 9=	144.00	OR	X$18=	
X42=	210.00	OR	X84=	
+140=		OR	+280=	
TOTAL	724.00	OR	TOTAL	

CLAIMS AS AMENDED - PART II

SMALL ENTITY OR OTHER THAN SMALL ENTITY

AMENDMENT A

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	*	Minus	**	=
Independent	*	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

RATE	ADDITIONAL FEE	OR	RATE	ADDITIONAL FEE
X$ 9=		OR	X$18=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT B

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	*	Minus	**	=
Independent	*	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

RATE	ADDITIONAL FEE	OR	RATE	ADDITIONAL FEE
X$ 9=		OR	X$18=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT C

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	*	Minus	**	=
Independent	*	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

RATE	ADDITIONAL FEE	OR	RATE	ADDITIONAL FEE
X$ 9=		OR	X$18=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20."
***If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3."
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

EXHIBIT G

CLAIMS ONLY

SERIAL NO.	FILING DATE
10134157	04/25/02

APPLICANT(S)

CLAIMS

	AS FILED		AFTER 1st AMENDMENT		AFTER 2nd AMENDMENT	
	IND.	DEP.	IND.	DEP.	IND.	DEP.
1	/					
2		/				
3		/				
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8		/				
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50						
TOTAL IND.	8					
TOTAL DEP.	28					
TOTAL CLAIMS	36					

	*		*		*	
	IND.	DEP.	IND.	DEP.	IND.	DEP.
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100						
TOTAL IND.						
TOTAL DEP.						
TOTAL CLAIMS						

* MAY BE USED FOR ADDITIONAL CLAIMS OR AMENDMENTS

FORM PTO-2022 (1-98)

U.S. DEPARTMENT OF COMMERCE
Patent and Trademark Office

*U.S. Government Printing Office: 1998 - 433-214/70303